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QUANTITATIVE PRICING METHODS FOR WARRANTIES ON AIR FORCE CONTRACTS

PHASE II FINAL REPORT

TASC

THE ANALYTIC SCIENCES CORPORATION

TR-5266-3

QUANTITATIVE PRICING METHODS FOR WARRANTIES ON AIR FORCE CONTRACTS

PHASE II FINAL REPORT

Prepared Under:

Contract No. F33615-85-C-5110

For

The Air Force Business Research
Management Center
Wright-Patterson, AFB Ohio 45433

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1. EXECUTIVE SUMMARY

This phase of the project to develop Quantitative Pricing Methods for warranties on Air Force contracts for the Air Force Business Research Management Center (AFBRMC) required the development of a quantitative model to estimate warranty costs. This report documents the research that was conducted to develop the model, provides the rationale for selecting specific cost estimating relationships, and explains the details of the model.

1.1 DEFINITION OF TERMS

Although the title of this project calls for the development of pricing methods, the statement of work clearly specifies that a tool for warranty cost estimating is the desired product. Since price analysts and system cost analysts in the Department of Defense come from different functional areas (Contracting and the Comptroller) and have individual requirements and methodologies, it is important that the proper audience be targeted. The model developed for this project is intended to be used for warranty cost estimating and therefore fits in the area of expertise occupied by the Comptroller's cost analysts. It is not intended for, nor will it meet the needs of the Contracting community's price analyst.

1.2 RESEARCH

In fulfilling the requirements of this phase of the project, TASC capitalized on its broad corporate warranty background

and specifically on the knowledge gained in supporting the Air Force Product Performance Agreement Center over the past four years.

The principal thrust of the research was to develop cost estimating relationships (CERs) that could serve as reliable predictors of warranty cost.

1.2.1 Research Targets

Three broad areas of research were conducted in order to gain new information or to update existing data. The areas of interest included:

- Government Programs -- Considerable data was in hand from the outset and was updated where possible. Those organizations that previously had warranty experience were contacted again
- Commercial Airlines -- The commercial air carriers have made extensive use of warranties and was an area of prior research. Two of the major carrier previously studied were contacted to determine the current status in the industry
- Automobile Industry -- Auto manufacturers also have extensive warranty experience and an excellent data feedback loop. Unfortunately, this industry will not share their information outside of individual corporations
- Defense Contractors -- A representative sampling of firms engaged in weapon development and manufacturing were contacted to learn of warranty costing techniques. No one had developed a quantitative costing methodology; however, one company -- Martin Marietta Denver -- is engaged in developing a qualitative methodology.

1.2.2 Potential CERs

This report covers a series of attempts to establish warranty cost estimating CERs. We considered such elements as the impact of competition, length of development schedules, and item unit cost. Item costs emerged as a reliable predictor of warranty cost and a set of curves and supporting data is presented to explain the analysis.

1.3 MODEL DEVELOPMENT

The cost estimating model developed uses the data (prediction) from the item unit cost to warranty unit cost relationship and then creates upper and lower bounds for the estimate through the use of three risk factors.

Research has shown that the state of technology employed in a weapon will impact risk. Radical or very extensive technology jumps tend to increase risk, and since a purpose of warranties is to deal with or reduce risk the warranty cost in a high technology program is likely to exceed that found in a lower risk instance.

The degree of schedule concurrency also impacts risk and the warranty cost in a highly concurrent program will tend to be more than in a program with a more orderly schedule.

The last risk factor is concerned with the length of the production schedule. Long production runs tend to lower risk and result in less expensive warranties.

The current state of the model is in manual form only. During Phase IV of this project, the model will be automated according to the specifications directed by the AFBRMC.

1.4 STATUTORY WAIVERS

A requirement of this phase is to demonstrate how the quantitative cost model could be used to request a waiver from the requirements of the 1985 warranty statue.

The cost model is just one part of the process to obtain a statutory waiver. The cost effectiveness of the potential warranty must also be determined. TASC has developed and automated a proven, effective cost benefit analysis procedure. This software currently resides on a large computer. During Phase IV of this project, the cost benefit analysis software will be re-designed to operate on a Micro-Computer. The cost benefit methodology coupled with the quantitative estimating model will provide the basis for determining warranty cost effectiveness. A non-cost effective warranty is grounds for a waiver from the requirements of the statute. An excerpt from the Air Force Product Performance Agreement Criteria Automated Division Support System User's Guide, developed by TASC, that details the procedure for performing a Cash Benefit Analysis is included as an Appendix to this report.

2. INTRODUCTION

Phase II of the project to develop Quantitative Pricing Methods For Warranties On Air Force Contracts has been completed. The successful accomplishment of the Statement of Work (SOW) tasks for this phase is central to the objectives of the entire project, since the work that remains is contingent upon the development of a practical warranty cost model.

It is appropriate, at the outset of this report, that we clarify what this model is and its capabilities.

2.1 COSTING VS. PRICING

The title for this project suggests that a quantitative tool will be developed for the use of price analysts. The project SOW, however, in paragraph 4.2.2 states:

> "Develop and validate a quantitative cost model which shall provide the program manager with an independent estimate of contract costs of a warranty."

Therefore, it appears that a warranty cost estimating model is the desired outcome of this project. This distinction is important because cost estimators and price analysts in the Department of Defense (DoD) form two separate functional areas of responsibility.

2.1.1 Definitions

The following definitions were taken from the National Estimating Society (NES) dictionary:

- SYSTEMS COST ANALYSIS: (1) The analysis of a weapon system (or support system or other kind of system); the deduction of the concept for operating, maintaining, and supporting the system; the accumulation of comparable and appropriate cost and technical data; and the estimation of the costs of all or a portion of its life cycle. (2) In the Department of Defense, this activity is called "cost analysis," and the organization performing it (called by the same name) is usually under the comptroller; whereas the price analysis organization which evaluates contractors' sales proposal costs or prices is in another organization - usually the production and control activity

- PRICE ANALYSIS: The process of examining and evaluating a prospective price without evaluation of the separate cost elements and proposed profit of the individual offeror whose price is being evaluated. It may be accomplished by: (a) a comparison of submitted quotations, (b) comparison of price quotations and contract prices with current quotations for the same or similar items, (c) the use of parameters (dollars per pound, for instance), or a comparison of proposed prices with independently developed estimates.

If we continue to refer to the output of this project as a pricing model, it will raise the expectations of the price analysis community without cause. Additionally, the warranty cost estimating model developed under this project does not respond to the needs of a price analyst.

The TASC monthly status report for May 1986 contained a discussion of these issues and recommended that the project name be

changed to "A Quantitative Cost Estimating Model for Warranties on Air Force Contracts." None of the foregoing alters the substance of the research efforts since the cost estimating approach we developed responds to the SOW. However, since perceptions and user acceptance of a product can be a fragile thing we believe it important that the appropriate body of potential users be properly identified.

2.2 REPORT OUTLINE

The details of Phase II effort are presented in Section 3 of this report. In Section 3.1 the research plan will be reviewed in order that the intended path can be understood. The actual approaches taken as the research was underway are presented in Section 3.2. A discussion and the results of the statistical tests made of the data is in 3.3. The model is presented in Section 3.4 and Warranty Cost Benefit Analysis in Section 3.5. Finally, a summary of research findings are presented in Section 4.

3. TECHNICAL DISCUSSION

3.1 THE RESEARCH PLAN

One of the outputs of Phase I of this project was a plan describing the manner in which the research would be conducted. That plan is entitled: Quantitative Pricing Methods Management Plan and dated 22 October 1985. It is available through the Air Force Business Research Management Center. Although the plan will not be duplicated in this report, the research methodology will be reviewed.

3.1.1 Existing Warranty Cost Estimating Capability

TASC has been extensively involved in warranty research, development and analysis for more than ten years. Our research has shown that little quantitative warranty cost estimating capability exists either in the government or in the private sector. In general, historical rules of thumb without any real data to support them have been used to generate warranty costs for contract proposal purposes. Therefore, since this condition was well known, TASC proposed from the outset to use a parametric approach using cost estimating relationships (CERs) as the most practical solution to the problem of determining a warranty cost estimating model.

3.1.2 Developing Cost Estimating Relationships

The first step in data analysis is to develop the technical parameter relationships that are expected to affect warranty costs. The exact process of identifying candidate relationships

is an iterative one based on detailed parametric analysis and the cost analyst's judgment. Initially, the explanatory variables are carefully analyzed to reduce the number of variables down to those that are in fact the causal factors, as opposed to those that are reflecting the influence of other variables. Once this refinement process has been completed, the remaining variables are then plotted against each other to determine if there are any interdependencies remaining and what the relationship is among the variables. This procedure of iterative scatter diagramming and analysis is continued until the underlying causal effects are identified and meet the test of reason. It should be noted that in this process there is no attempt to arrive at a single functional relationship, but rather to define a set of equations that are judged to be potentially good predictors of cost.

In order to develop/construct appropriate CERs we examined a series of variables that offered the possibility of being reasonable warranty cost predictors. These were:

- The length of the production cycle and the relationship(s) of various program milestones, e.g., production approval date, rollout and first flight date, number of units produced
- The relationship between the unit cost of the item being procured and the potential cost of the warranty. In a similar vein, we were also interested to see if item repair costs were related to warranty cost
- The impact of relatively large advances in technology was another area of interest
- Finally, we intended to determine if a relationship existed between the warranty type selected and the cost thereof.

The reason the general categories listed above were chosen is because they each has the possibility of addressing program risk. For example, a schedule that allows for a reasonable length of time to proceed through development and initial testing enables the developer to have a reasonable opportunity to eliminate many if not all of the "bugs" from the product. In other words, there is a possibility of reducing risk by following an orderly schedule which may in turn be reflected in a more reasonable warranty cost.

3.1.3 Model Development Guidelines

It is the desire of the Air Force Business Research Management Center (AFBRMC) that this model have some specific features as directed in paragraph 6.0 of the SOW:

- The contractor must use the current versions of ANSI standard COBOL or FORTRAN programming languages for all phases of software development, or obtain special documented prior approval from AF/ACD for deviation. Statements and subroutines written in non-standard code shall in all cases be clearly identified as non-standard code and shall, where possible, be separated from the standard code

- All software is to be composed of discriminately modularized programs with each of these modules containing micro structured units being functionally and primitively discrete and organized in a flexible and modifiable substructure within each program

- The design must be modular with minimal independence of the operation of one module on the internal details of another

- The code will be self-explanatory with in-line documentation and with input and output specifications provided in each module header block. The documentation of units, modules, programs, systems, and interactions among them, shall be complete and each shall be separately identifiable

- Any portions of the software which explicitly depend on operating system properties will be contained in a small number of modules. This is intended to facilitate interfacing the software with other different systems.

In addition to the foregoing software principles, the AFBRMC also provided the following guidance:

- The model must operate on a microcomputer, specifically the Zenith Z-100 machine
- Inputs to the model must be of a general nature of the type readily available even at early program stages. The model should not, for example, require the user to develop reliability estimates or growth parameters - an acceptable input parameter could be recurring unit cost.

3.1.4 Data Gathering

TASC has been the support contractor to the Air Force Product Performance Agreement Center (PPAC) since 1982 and in that role has conducted extensive data searches across the Air Force Systems Command (AFSC) and the Air Force Logistics Command (AFLC). Our previous research produced considerable warranty data/information, but no direct documentation to support or explain cost. Discussions were also fruitless with representatives of the following:

- Northrup
- General Dynamics - Convair
- Lockheed Georgia
- Grumman
- LTV Aerospace

- Boeing Military Airplane Company
- Lockheed - California
- Rockwell International
- General Motors - Delco Division
- Hughes
- Westinghouse
- Goodyear.

Another potential source of warranty data is the commercial airline industry, possibly the largest community of warranty users anywhere. Previously, in support of the PPAC, TASC had visited a cross-section of air carriers to learn of their use of warranties and the manner in which they determined cost effectiveness. The companies researched were:

- American
- TWA
- Eastern
- Delta
- Republic
- Ozark
- Piedmont
- Comair
- Wright
- Air Wisconsin
- Midwest Express.

In each instance, warranties were used extensively and were never separately priced. Not even one company would admit to knowing the cost of warranties or how those costs may have been determined.

Despite the results of previous research, additional data gathering was planned for this project in order to determine if new information was available. Obviously, the purpose of the data gathering is to provide the information necessary for establishing the cost estimating relationships that will then support the warranty cost estimating model.

3.1.5 Research Plan Summary

To develop a model capable of estimating warranty cost TASC embarked on the following course of action:

- Conduct a data gathering phase to supplement and/or validate existing warranty information. The principal thrust of this research would be aimed at determining how warranty costs were computed. Information would be sought from government sources in AFSC and AFLC, commercial business such as airlines, and automobile manufacturers. The output of this phase of the research would be a series of potential variables that may prove to be reasonable predictors of warranty cost
- Following the data collection activity analysis will be performed to establish the CERs and to construct the model.

3.2 RESEARCH EXECUTION -- DATA COLLECTION

Using recent TASC experience in warranty research as a baseline, we began this effort by re-engaging previous sources to ascertain the current status of on-going programs. The results of that search are presented in this section.

3.2.1 Commercial Airlines

There was a high degree of uniformity in the application and implementation of warranties in the commercial airline industry noted when TASC initially probed this area in the 1984-1985 time frame. Some of the common features are:

- Warranties are not separately priced
- A direct result of the first item is that cost benefit analyses of having warranties is not performed
- A concentration on processing claims against the warranty to offset repair costs. For a large carrier these claims average $22.0M per year.

In support of this project, we re-contacted Eastern and Delta airlines, and found no changes in warranty policy or procedures. Based on this information, we eliminated the airline industry as a potential data source for developing a warranty cost estimating model.

3.2.2 Automobile Manufacturing

Warranties in the auto industry are primarily marketing tools. If the manufacturer can develop the perception in the consumer's mind that car x is superior to all others because x has a six year and 60,000 mile warranty and that in turn generates increased market penetration, then the use of warranties is successful.

This industry has detailed warranty cost data but it will not share the information. Perhaps this should not be a surprise given the competitive nature of the business and that warranties are a marketing/sales tool. For these reasons or others, we were unable to penetrate this industry.

3.2.3 Department of Defense

Although warranties have been used on DoD weapon acquisition programs for more than a decade, their selection, analysis, implementation, and administration were largely a matter of individual choice since there was no over-all policy or direction governing their use. Based on research performed previously for the PPAC by TASC no documentation survived to attest to the manner in which cost benefit analyses or warranty cost estimates may have been accomplished. This research encompassed an initial data base of all contracts issued by AFSC or AFLC with a face value in excess of $5.0M during the period 1977 thru 1982. Nearly 2,000 contracts fit that description. The number was reduced to those that had warranties or guarantees by contacting each of the AFSC Product Divisions and AFLC Air Logistics Centers. When the standard (Correction of Deficiencies, Warranty of Supplies, etc.) clauses were omitted and attention was concentrated on performance warranties (Reliability Improvement, Mean Time Between Failures, etc.) fewer than 50 warranted programs were found. The research was concentrated on performance warranties since these were typically, although not always, separately priced in the contract. The standard clauses were generally provided at very low or no cost. That earlier data search uncovered warranty information at the following locations:

- Aeronautical Systems Division
- Electronic Systems Division
- Space Division
- Oklahoma City ALC
- Warner Robins ALC.

Since these organizations were good sources of information previously and since we were generally aware of recent progress, the research for this project was concentrated in these same locations. The data collection results were as follows:

- Oklahoma City ALC -- Some of the most useful data ever obtained came from this Air Logistics Center on the following programs:

  - Standard Inertial Navigation Unit
  - F^3 (Form, Fit, Function) Inertial Navigation System
  - Digital Amplifier Unit for the B-52, C-130, and C-135

  Standard Central Air Data Computer

  Standard Precision Inertial Navigation Unit.

These programs provided the data that enabled the breakthrough in establishing initial CERs, as we reported in the September Monthly Status Report.

- Electronic Systems Division -- Data on just two programs, the Miniature Receiver Terminal and MILSTAR; however, neither yielded information that explained warranty cost buildup

- Warner Robins ALC -- As in our previous research, this Air Logistics Center was found to be very active in the warranty area. The following programs have warranties or will have them.

Engineering Services	Supplies/Services
Telemetry Pack Frequency	Supplies/Services
Supplies/Services	Power Supply
Filter Assy	Output High Band
Retrofit Kit	TWT, Low Band Pulse
TCTO Kit	Band 12, Backward Wave
Door Assy	Traveling Wave Tube
Services	TWT, Output High Band
Proximity Switch Sensor	Jammer Control Panel

Overhaul of Crack, fire, rescue and structural fire trucks	Gen/Driver
Remanufacture/Mod truck mounted snow plows	Design, Fabrication, Integration
Truck, Lift Fork	RF Calibrator
Services/Supplies	Receiver
Air Cargo Pallet	Amplifier/Detector
Frequency Converter	Supplies/Services
Engineering Services	Cable Assy Spec
Container Assy Flex	Services/Supplies
Truck, Aircraft Refueling	Kit A
Hydrant Hose	Exhaust Cone
Truck, Aircraft Cargo	Maiant/Modification of C130 Acft
Trencher	High Speed Copy Recorder level
Compressor	Inspection
Compressor	Model 226A Tape Reader
Milling Machine	Modification Kit
MCIA Compressor	Services.
Compressor Type	

Unfortunately, none of the warranties for these programs were of the performance type nor were they separately priced.

- Aeronautical Systems Division -- There has been a great deal of warranty activity at ASD and much of it in the performance area. Specific cost information is available and cost benefit analyses have been performed on four such programs by TASC. However, one of the programs has restricted access and the other three, F-111 ECM update, Air Defense Fighter, SRAM II are either in or have just completed source selection. TASC performed the warranty analysis as part of the Source Selection Evaluation Board (SSEB) and once the Source Selection Authority (SSA) releases the data for public use it will be incorporated into this project.

  Other ASD programs that were reviewed were:

  - F-100 Engine
  - A-10 Inertial Navigation System
  - TF 34 Engine
  - F-16 Avionics

- Space Division -- Although the Peacekeeper SPO will have warranties on its system they have not been implemented. We were able, however, to obtain some cost data to support the analysis for this project.

3.2.4 Data Collection -- Summary

We believe that the data reviewed for this project is representative of the state of warranty data across the DoD. In fact, the relative scarcity of cost information supports the need for methodologies to estimate warranty cost. As previously noted in this report the need is just as valid in the defense industry as it is in the government. It seems implausible that anything as potentially costly as the remedies required under a performance warranty would receive such scant attention. However, several years of research bears this out, and this is the primary reason that more detailed information is not available.

Another aspect of the data is that it is concentrated in avionics or electronics equipment. While it is true that some engine warranties exist, e.g. TF34, F100, T700 (Army Blackhawk Helicopter) and the alternate fighter engine these are of fairly recent ventage. There are several reasons for the electronics concentration condition to exist. Probably the most important reason was the August 1973 memorandum issued by the Assistant Secretary of Defense for Installations and Logistics and the Director of Defense Research and Engineering to the service secretaries on the trial use of warranties in acquiring electronic subsystems. The memo stated:

> "In industry, extensive use is made of warranties, thereby establishing the manufacturer's responsibility to provide a usable and available product during a period of time. Accordingly, it is requested that a trial application of warranties be utilized in the acquisition and initial

> operational support of a number of electronic subsystems to help determine the scope and benefit warranties may have for the DoD as well as effective management approaches."

In the wake of the DoD memo, the services began to obtain performance warranties and their use gradually spread. However, warranty applications generally remain at the subsystem or component level. There are no DoD examples of performance warranties being applied to an entire system such as an airplane or ship, although they had been planned for the C-17 and T-46. Full system warranties were approached on the C-9, T-43, and KC-10. However, these applications were special in that the aircraft being procured were:

- Derivations of commercial aircraft -- DC-9, B-737, and DC-10
- Purchased in rather limited quantities
- Intended to receive contractor support throughout the life span of the aircraft.

In each of the above cases, the Air Force contracted for a specific mission availability guarantee. The spares support was typically managed through a Contractor-Owned and -Managed Base Supply (COMBS) system. The latter allows the Air Force to be the beneficiary of the world-wide support system developed to support commercial air carriers.

Two features therefore characterize DoD warranty experience:

- Avionics/electronic equipment dominates the data base
- Supporting cost data from government and industry is virtually non-existent.

The applicability of this data for CERs to predict warranty cost will be discussed later in this report.

3.3 RESEARCH EXECUTION -- ANALYSIS

In attempting to establish cost estimating relationships to predict warranty cost, TASC explored several options. The results of this analysis will be presented in this section.

3.3.1 The Competitive Environment

Research into the impact of a continuing competitive environment on development and production programs has clearly established that competition improves quality and lowers price. Figure 3.3-1 portrays a typical cost improvement curve in a sole source situation. The curve reflects cost reductions as quantities increase. The insertion of a second source, however, causes significant changes in the shape of the curve. Figure 3.3-2 illustrates the impact of a second source before the original source responds.

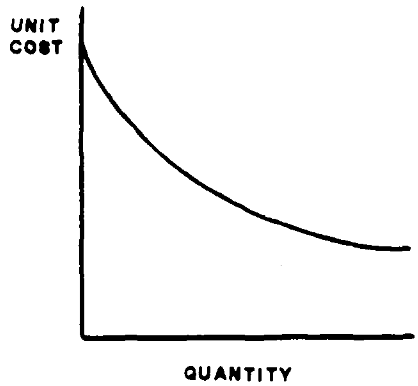

Figure 3.3-1 Sole Source Cost Improvement Curve

The cost improvement curve for the second source initially begins higher than the first source for any given quantity, but the

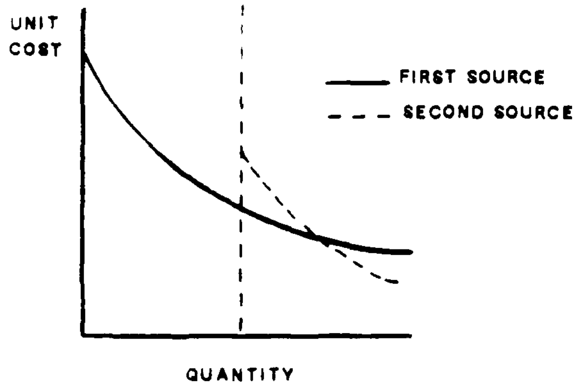

Figure 3.3-2   Dual Source Cost Improvement Curve

rate of improvement is greater than the first source and soon results in a unit cost well below the first source. It should be noted that these curves, while accurately depicting the impact of a second source on cost improvement, are generic models to illustrate the concept. The actual shape of the curves, the displacement when the second source is added and the relative rate of improvement thereafter are dependent upon the type of program involved.

Figure 3.3-3 illustrates that the first source will usually respond to the behavior of the second. Note that the first source will take steps to reduce cost (change the slope of the cost improvement curve) in order to be a viable competitor.

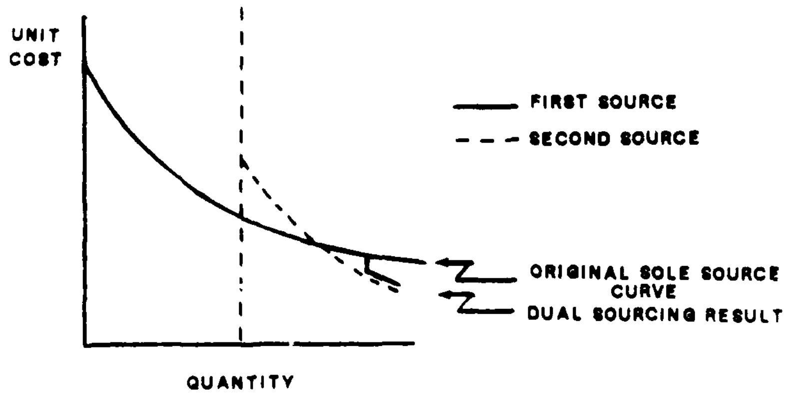

Figure 3.3-3   Second Source Price Behavior

TASC has been deeply involved in researching the impact of competition on weapon acquisition programs for nearly a decade. In conjunction with the Center for Naval Analyses, TASC surveyed program managers on the effect of development competition. The results are shown in Fig. 3.3-4. Note that in four of the five programs lower technical risk resulted from the competitive environment. We believe that such risk reduction results in lower warranty costs.

PROGRAM	CONTROL R&D COSTS		ENHANCE DESIGN	LOWER TECHNICAL RISK
AN DVT		X	X	X
TB-23	X	X	X	X
MULTI-MODE RECEIVER	X		X	
ASPJ	X		X	X
ANTENNA COUPLERS		X	X	X

Figure 3.3-4 Effects of Navy Development Competition

TASC has also completed an assessment of the impact of competition on five Army programs and these are shown in Fig. 3.3-5. As in the Navy example, risk was reduced in four of the five programs.

The Alternate Fighter Engine (AFE) acquisition featured General Electric and Pratt Whitney in head to head competition. The plan for the acquisition/production phase was to maintain both

PROGRAM	PERFORMANCE	CONTROL R&D COSTS	REDUCE PROCUREMENT COST	PROGRAM STAFFING	MANAGEMENT COMPLEXITY	REDUCE RISK
MLRS	+	+	+	○	+	+
HMMWV	+	+	+	○	−	+
AH-64	+	○	○	−	−	+
SINCGARS	+	+	□	○	○	+
AN/TCC-30	□	+	+	−	−	□

+ POSITIVE EFFECT — NEGATIVE EFFECT ○ NEUTRAL EFFECT □ UNKNOWN

Figure 3.3-5 The Effects of Army Development Competition

sources by dividing the annual buy between the two companies. At the time of initial proposal submission, the warranty price marked the essential differences between the two bidders. The GE warranty price amounted to five percent of engine price, while Pratt's varied from five percent to 33 percent of engine price depending on the production share received. Under the pressure of competition, however, Pratt was forced to substantially reduce its warranty price.

In examining the correlation between competition and the cost of a warranty we found that the relationship was indirect. As the preceding data shows competition, and particularly continuing competition, e.g., dual sourcing, tends to produce lower program costs as compared to sole source procurements. The lower item unit cost tends to drive warranty cost for, as we shall see later, there is a strong correlation between item and warranty cost. Of course the respective strategies of General Electric and Pratt Whitney in the Alternate Fighter Engine example cited above appears to be an exception to the rule.

3.3.2 Development Duration

Programs that experience relatively long development programs are typically lower risk efforts in production and are less troublesome in the field. The T700 engine for the Army's UH-60A Blackhawk helicopter had a relatively long development schedule by General Electric and it proved to be one of the most successful helicopter engines ever developed.

There are, however, other factors that could cause a lengthy development schedule that may not be contributors to system reliability and lower risk. Severe technical issues may not be fully resolved even with a long schedule and reliability problems may persist in the field. TASC recently conducted warranty analysis on a Remotely Piloted Vehicle program that has more than six and a half years in development. Despite that duration and considerable government investment in reliability enhancement projects there is low probability that the system will meet its performance specifications.

Funding problems often cause schedule slips and could give the appearance of an orderly development schedule when in fact that may not be the case.

Given the variables, a reasonable correlation could not be established.

3.3.3 Production Schedule Duration

Long (more than three years) production schedules may contribute to more reliable field operations. Extended production schedules allow for gradual maturation of the product with the opportunity for making low cost improvements to products already delivered thus reducing risk and potential warranty costs.

A few programs have had very long production programs, some extending over 20 years. For example:

- The Lockheed C-130
- McDonnel Douglas A-4
- Boeing 727
- The Volkswagon "Beetle."

Each of the above products enjoyed an exceptional degree of field reliability. However, we do not believe that the field performance is necessarily linked to the so-called Learning Curve phenomenon. That is, that a manufacturing process (or almost any process) when iterated a sufficient number of times by the same group of people will get progressively more efficient and effective. While there may be some element of learning that drives improved reliability, e.g., improved production quality, we postulate that improved product performance is basically derived from evolutionary product changes/improvements.

Although there is a clear relationship between the risk associated with short production schedules as compared to long ones there is insufficient quantitative evidence to establish a cost estimating relationship. The data does, however, suggest that schedule risk is of sufficient impact to be included as part of the model bounding process discussed later in this report.

3.3.4 Unit Cost vs. Warranty Cost

There are two principal characteristics that this cost estimating model must have: First, that it be user friendly; and second, that input data requirements must be consistent with the type of information available within a program office at the time warranty analyses are customarily conducted.

As we performed the analysis to establish CERs for a warranty cost estimating model, item unit cost emerged as a reasonable working hypothesis to predict warranty cost. Therefore, in this section, we will present the data and the rationale to support the first of three potential approaches for predicting warranty cost. The data presented was taken from a series of inertial navigation systems contracts as well as a variety of other systems. The inertial navigation system contracts included:

- Negotiated hardware prices for five years for fighter-attack, transport, strategic aircraft and helicopters
- Negotiated warranty prices for each hardware type, also for five years
- Negotiated contractor depot support prices for each aircraft class for five years.

It is important to note the following:

- Reliability Improvement Warranty (RIW) for a period of five years after delivery of the first item
- The contracts included priced options for Contractor Depot Support (CDS) for a period of five years to commence after the RIW period is complete
- Three contractors are involved: Singer, Honeywell, and Litton. Of these, Singer had a uniform hardware price for all clauses of aircraft <u>including</u> the F-15. Honeywell and Litton hardware prices were uniform across all aircraft clauses <u>except</u> for the F-15.

Although the data that follows is strongly represented by inertial navigation systems, the results appear typical for electronic components. According to the Aerospace Guidance and Metrology Center (AGMC) at Newark AFS, Ohio INS electronic components, by far, comprise the largest number of failures and repairs.

Similarly, Delco Electronics reports that they offer maintenance contracts for the Carousel INS (of which over 7,000 have been sold). Delco's repair fee is $1.25 per operating hour, and of that amount, just two cents are budgeted for mechanical parts, e.g., the gyro and the accelerometer with the balance for the repair of electronic components.

It would certainly be more advantageous if the empirical data were more broadly distributed across equipment classes and uses, however, that is not the nature of the data. Military performance warranties have been concentrated in electronic system and while that will be changing as a result of 10 USC 2403, there is insufficient information available at this time to reach any conclusions as to how the empirical data may be affected by other equipment classes.

Table 3.3-1 through 3.3-3 present the pertinent data for these programs. All cost/pricing data are negotiated values extracted from the applicable contracts and reflect recurring unit prices.

- <u>Item Unit Cost</u> -- Except for the first lot buy, which was specified all other options were computed at 100 per lot
- <u>Total Warranty Cost</u> -- Total cost for the run of the contract, or five years for the first lot, four for the second and decreasing one year in total coverage for each subsequent lot
- <u>Annual Warranty Cost</u> -- Total warranty cost divided by the respective period of performance for each lot
- <u>Contractor Depot Support Cost</u> -- Negotiated contractor repair costs - by aircraft class, i.e., transport, strategies, helicopter, etc., for support to commence after the RIW expires. these costs are interesting since they represent negotiated costs to repair. Clearly costs such as these are imbedded in the warranty cost numbers for the RIW period.

TABLE 3.3-1

HARDWARE, WARRANTY, AND DEPOT SUPPORT COSTS
PART I

VENDOR/PROGRAM	ITEM UNIT COST	WARRANTY UNIT COST (TOTAL)	WARRANTY UNIT COST (ANNUAL)	CDS COST	TOTAL/ANNUAL WARRANTY COST % UNIT
SINGER HANES INS	135,089	20,383	4,077	3,163	15.0/3.0
SINGER (OPT #1)	138,256	17,960	4,490	3,163	13.0/3.3
SINGER (OPT #2)	140,582	14,358	4,786	3,359	10.2/3.4
SINGER (OPT #3)	150,749	10,545	5,273	3,566	7.0/3.5
SINGER (OPT #4)	159,164	4,734	4,734	3,788	3.0/3.0
HONEYWELL STD INU	91,300	11,500	2,300	2,213	12.6/2.5
HONEYWELL (OPT #1)	96,650	11,500	2,875	2,213	11.9/3.0
HONEYWELL (OPT #2)	101,000	11,000	3,666	2,334	10.9/3.6
HONEYWELL (OPT #3)	105,600	7,800	3,900	2,463	7.4/3.7
HONEYWELL (OPT #4)	110,400	4,000	4,000	2,598	3.6/3.6
HONEYWELL (F-15 #1)	105,750	14,500	3,625	2,557	13.7/3.4
HONEYWELL (F-15 #2)	110,300	12,500	4,167	2,698	11.3/3.8
HONEYWELL (F-15 #3)	115,100	8,500	4,250	2,846	7.4/3.7
HONEYWELL (F-15 #4)	120,150	4,600	4,600	3,003	3.8/3.8

TABLE 3.3-2

HARDWARE, WARRANTY, AND DEPOT SUPPORT COSTS
PART II

VENDOR/PROGRAM	ITEM UNIT COST	WARRANTY UNIT COST (TOTAL)	WARRANTY UNIT COST (ANNUAL)	CDS COST	TOTAL/ANNUAL WARRANTY COST % UNIT
LITTON STD INU	84,994	29,580	5,916	2,013	34.8/7.0
LITTON (OPT #1)					
FIGHTER/ATTACK	85,000	11,885	2,971	2,894	14.0/3.5
TRANSPORT	85,000	15,620	3,905	2,013	18.4/4.6
STRATEGIC	85,000	11,119	2,780	2,894	13.1/3.3
HELICOPTER	85,000	19,013	4,753	3,342	22.4/5.6
F-15	90,000	16,491	4,123	2,917	18.3/4.6
LITTON (OPT #2)					
FIGHTER/ATTACK	85,000	11,645	3,882	3,056	13.7/4.6
TRANSPORT	85,000	13,505	4,502	2,108	15.9/5.3
STRATEGIC	85,000	13,505	4,502	3,056	15.9/5.3
HELICOPTER	85,000	18,192	6,064	3,443	21.4/7.1
F-15	90,000	12,592	4,197	3,097	14.0/4.7

TABLE 3.3-3

HARDWARE, WARRANTY, AND DEPOT SUPPORT COSTS
PART III

VENDOR/PROGRAM	ITEM UNIT COST	WARRANTY UNIT COST (TOTAL)	WARRANTY UNIT COST (ANNUAL)	CDS COST	TOTAL/ANNUAL WARRANTY COST % UNIT
LITTON (OPT #3)					
FIGHTER/ATTACK	85,000	7,911	3,955	3,352	9.3/4.7
TRANSPORT	85,000	5,746	2,873	2,283	6.7/3.4
STRATEGIC	85,000	7,911	3,955	3,352	9.3/4.7
HELICOPTER	85,000	9,450	4,725	3,720	11.1/5.5
F-15	90,000	6,783	3,392	3,503	7.5/3.8
LITTON (OPT #4)					
FIGHTER/ATTACK	85,000	3,688	3,688	3,443	4.3/4.3
TRANSPORT	85,000	2,879	2,879	2,361	3.4/3.4
STRATEGIC	85,000	3,688	3,688	3,443	4.3/4.3
HELICOPTER	85,000	5,067	5,067	3,881	6.0/6.0
F-15	90,000	3,052	3,052	3,493	3.4/3.4

the purpose of comparison, however they are shown as they might appear during the RIW as a measure of what portion of warranty cost is risk and what portion is solely maintenance or repair cost. Please note we are not suggesting that the government paid twice for the same service, i.e., warranty and CDS. The depot support cost data as contracted with warranty cost is for illustration only.

Total/Annual Warranty Cost of Unit -- This column allows for a comparison of warranty costs expressed as a percentage of unit cost.

It is interesting to note the relative consistency in the annual warranty cost when expressed as a percentage of hardware unit cost. Over 55 percent of the annual costs were less than four percent per year and over 90 percent were less than six percent.

The cost of a warranty is generally considered to be an expression of financial exposure risk that the parties to the warranty may encounter. Typically that risk takes two forms:

- The cost to repair failed items during the life of the warranty. This is usually determined by a projection of potential field reliability and an assessment of the attendant repair costs. The contractor's motivation is to produce a reliable product thus reducing failures and the attendant repair costs
- The possibility of a major system default that would require a "re-call" of all failed items followed by a system re-design and fleet retrofit. The risk of such an occurrence may be governed by a series of events such as:
  - Degree of technology change
  - System application (manned/unmanned, space, dormant)
  - Schedule concurrency
  - Length of production schedule.

In bidding the Contractor Depot Support costs, the offerors were identifying the potential repair cost. These dollars represent pure repair cost since there was to be no warranty in place at the time CDS was exercised. This data provides a rare insight into the manner in which those costs are viewed and in their magnitude. Even though the warranty and CDS were not in force simultaneously it is possible to generalize about the possible relationship of the two elements of warranty risk. For this set of contracts it appears that repair costs were more of a concern than the potential for a fleet-wide retrofit of the equipment. Notice, that the cost to repair failures is estimated to be the dominant share of the annual warranty cost. For example, since Contractor Depot Support costs represent the estimated cost to repair failures note that repairs accounted for over 70 percent of total warranty cost in the Singer contract.

Table 3.3-4, Hardware and Warranty Costs, presents the balance of the program data used to develop the cost estimating relationships.

Figure 3.3-6 graphically displays the tabular data in the preceding tables. There are 60 data points in Fig. 3.3-6 and they have the following characteristics:

- 73 percent are within ± 15 percent of the predicted cost curve
- In seven cases, twelve percent of the total, the actual contract warranty cost was lower than the predicted cost and outside of the 15 percent zone
- In nine cases, 15 percent of the total, the actual contract warranty cost was higher than predicted and outside the 15 percent zone
- Six data points on the $85,000 unit price line with a warranty cost of more than $4,000 were not used in the analysis. This data was considered to be outside of the relevant data considerations

TABLE 3.3-4

HARDWARE AND WARRANTY COSTS

VENDOR/PROGRAM	ITEM UNIT COST	WARRANTY UNIT COST (ANNUAL)
ARN-118 TACAN		
BASIC	$ 9,448	$ 680
OPTION #1	9,039	400
OPTION #2	8,504	350
OPTION #3	8,909	476
OMEGA NAVIGATION SYS	10,430	532
F-111 GYRO	6,040	440
ARN-123 VOR	1,377	148
R1963 GLIDESLOPE	682	61
CAROUSEL INS	54,063	2,292
KLYSTRON TUBE	890	56
AN/APN 209 ALTIMETER	4,412	434
ATTITUDE HDG REF. SYSTEM	27,121	1,208
RADAR ALTIMETER	13,026	696

- The dashed lines on either side of the predicted curve includes all the warranty cost cases that are within 85 percent of the predicted value at any point on the curve. There is insufficient data at any given value of item unit cost to support a more rigorous statistical approach. The 85 percent of predicted warranty cost was selected to describe the upper and lower boundaries because it was determined to be within reasonable estimating accuracy given the dispersion of the data

- The curve depicted in Fig. 3.3-6 was drawn considering that the Litton pricing data was anomalous, i.e., level unit pricing over all contract years. That approach was inconsistent with all other cost data.

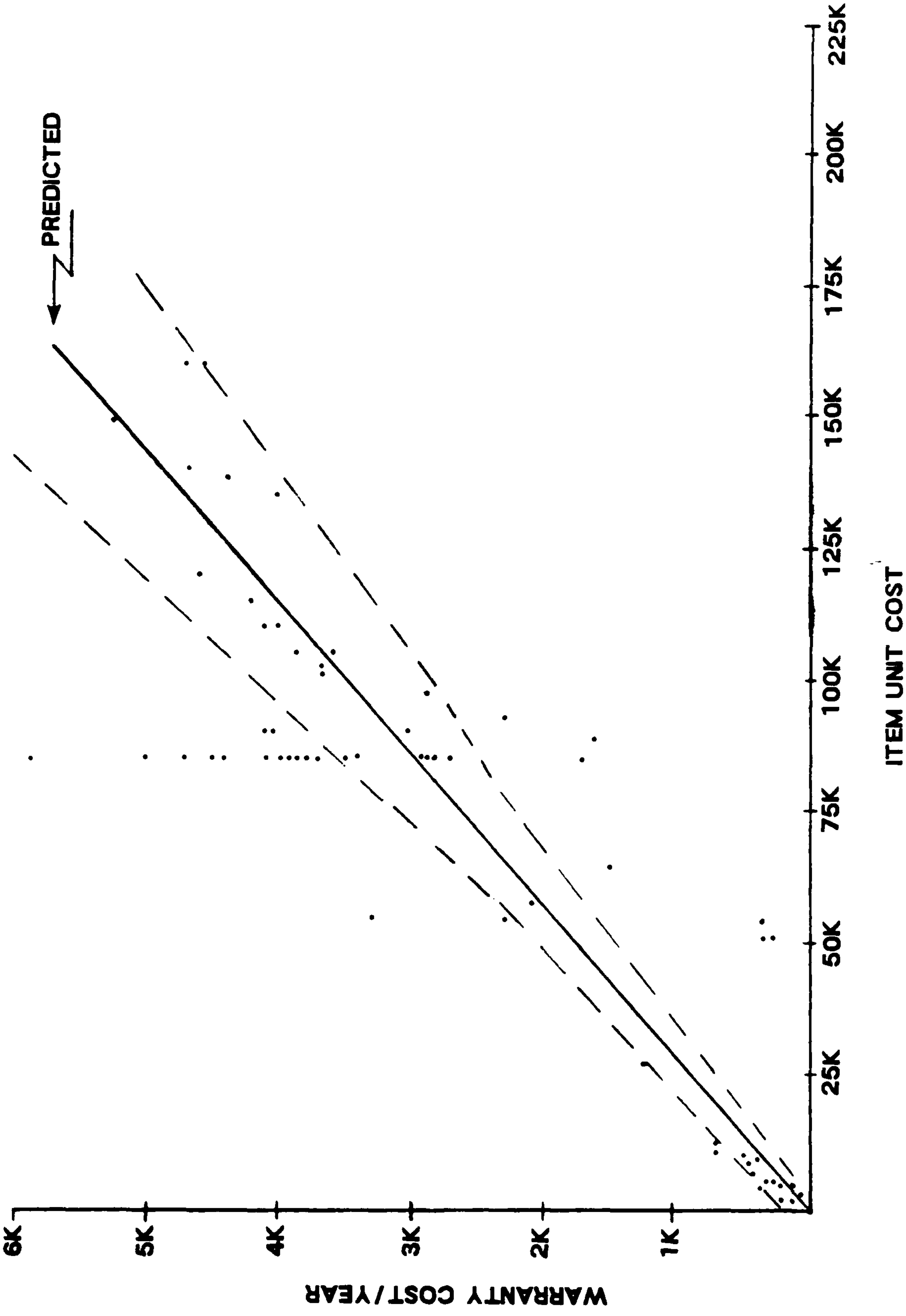

Figure 3.3-6 Unit Cost VS Warranty Cost

3.3.5 Repair Cost vs. Item Unit Cost

Item unit cost can also be used to predict repair costs per item per year. The curve in Fig. 3.3-7 was constructed from the data presented in Tables 3.3-1 through 3.3.3.

The correlation suggested by the curve in Fig. 3.3-7 is not surprising since high cost items normally cost more to repair than those of lesser cost. We would expect that a given item on a Mercedes costs more than a similar item on a Chevrolet. This curve can be useful as a means of cross-checking the warranty cost estimator derived with the methodology in Fig. 3.3-6. This can be done by using the cost to repair as an output value from Fig. 3.3-7 and then using repair cost as an input in Fig. 3.3-8 which is discussed in Section 3.3.6.

3.3.6 Repair Cost vs. Warranty Cost/Year

If repair costs are known, or have been predicted using Fig. 3.3-8 then a warranty cost estimate can be determined either as an initial estimating value, or as a cross-check for an estimate developed in another fashion.

The relationships depicted in this figure should not be a surprise since the data shown previously in Table 3.3-1 is the source for the information.

3.3.7 Statistical Testing

A series of three statistical tests were performed on the data presented in paragraphs 3.3.4 thru 3.3.6 to evaluate their utility as warranty cost estimating relationships. They are:

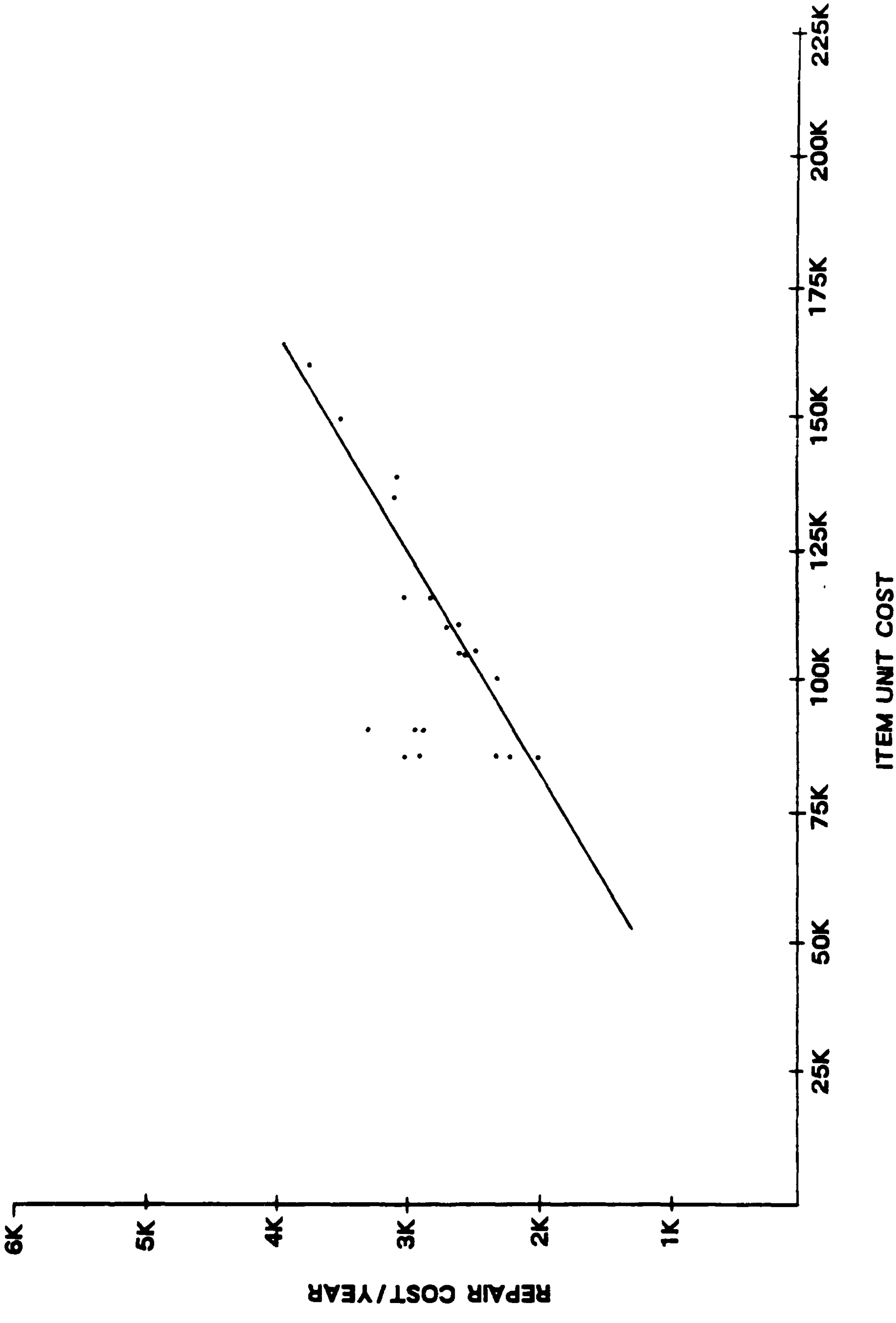

Figure 3.3-7 Unit Cost vs. Repair Cost

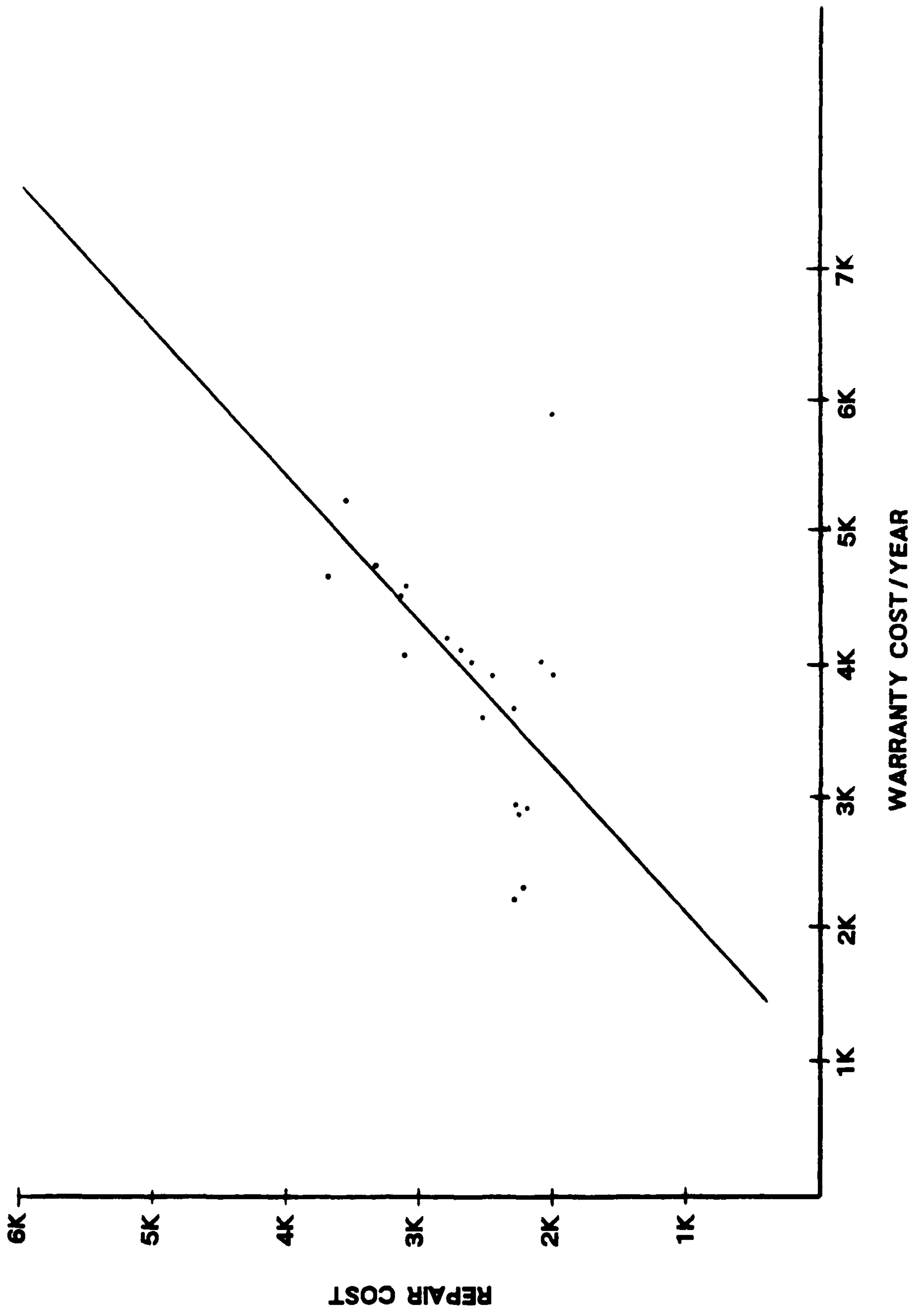

Figure 3.3-8 Warranty Cost vs. Repair Cost

- The coefficient of determination, R^2, is a measure of the amount of variation in cost that is explained by the independent variables. If all cost variation for an RIW could be completely explained by subsystem weight, then the R^2 value would be 1.0, which would suggest that weight is a perfect predictor. If, on the other hand, the weight is a relatively poor predictor, or its relationship to cost has been poorly formulated. Nonetheless, the closer R^2 is to 1.0, the more meaningful the relationship, provided it made sense in the beginning

- The "F" test is basically a test to determine whether the hypothesized relationship could have occurred merely by change. The F-statistic is the ratio of the explained variance to the unexplained variance. This "F" statistic value is compared against the critical "F" value for 95 percent significance, and if the "F" statistic is greater than the critical "F" value, the relationship is concluded to be too great to have occurred by chance

- The standard error of the estimate (SEE) is a third statistical test that relates how closely the estimated values of cost based upon the estimating equation compare to the observed cost in the data set. Therefore, the smaller the SEE, the closer the observed cost fits the estimated cost and, presumably, the better the relationship.

Table 3.3-5 presents the results of the testing. The test results show that the variables chosen are highly reliable predictors of warranty cost. Please note that even where the Litton anomalous prices (all at $85,000 per unit) are excluded from consideration there is little variance in statistical reliability.

TABLE 3.3-5

STATISTICAL TESTING
WARRANTY CERS

PREDICTED VARIABLE	INDEPENDENT VARIABLE	NUMBER OF CASES	EQUATION	R^2	(1.-PROBABILITY) FOR SIGNIFICANCE OF F-TEST	STANDARD ERROR OF EQUATION COEFFICIENT	NOTE
WARRANTY UNIT COST (ANNUAL)	ITEM UNIT COST	48	W=0.39I	0.94	<0.0001	0.00145	
WARRANTY UNIT COST (ANNUAL)	ITEM UNIT COST	32	W=0.36I	0.95	<0.0001	0.00133	CASES OMITTED WHERE ITEM UNIT COST = 85,000
WARRANTY UNIT COST (ANNUAL)	REPAIR COST	35	W=1.341R	0.95	<0.0001	0.0516	
REPAIR COST	ITEM UNIT COST	19	R=0.029I	0.94	<0.0001	0.00121	
REPAIR COST	ITEM UNIT	19	R=0.026I	0.97	<0.0001	0.00102	CASES OMITTED WHERE ITEM UNIT COST = 85,000

Tables 3.3-6 thru 3.3-10 present the detailed outputs that make up Table 3.3-5.

3.3.8 Analysis Summary

In conducting the search for and in performing the analysis to establish rational CERs to predict warranty cost, we have examined several areas. Some of these have been found to be useful while others have not.

The impact of sustaining competition throughout the procurement/production phase of the program has been shown to reduce overall acquisition cost. Although we have not been able to establish a direct link between programs that have used dual sourcing or

TABLE 3.3-6

STATISTICAL TESTING - OUTPUT

```
Page 3                          SPSS/PC+

        * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1       Dependent Variable..   W


Variable(s) Entered on Step Number
   1..    I



Multiple R                .96960
R Square                  .94012
Adjusted R Square         .93885
Standard Error         879.15902

Analysis of Variance
                       DF      Sum of Squares        Mean Square
Regression              1      570355565.49074    570355565.49074
Residual               47       36327267.50926       772920.58530

F =     737,92260          Signif F = .0000
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
Page 4                          SPSS/PC+

        * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1       Dependent Variable..   W


- - - - - - - - - - - Variables in the Equation - - - - - - - - - -

Variable               B       SE B       Beta          T    Sig T

1                 .03942  1.45127E-03   .96960     27.165    .0000

End Block Number  1  All requested variables entered
```

TABLE 3.3-7

STATISTICAL TESTING - OUTPUT

```
Page 3                          SPSS/PC+

      * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1      Dependent Variable..  W

Variable(s) Entered on Step Number
   1..    I



Multiple R               .97925
R Square                 .95892
Adjusted R Square        .95760
Standard Error        668.12469

Analysis of Variance
                        DF      Sum of Squares      Mean Square
Regression               1     323041799.47031   323041799.47031
Residual                31      13838108.52967      446390.59773

F =    723,67519          Signif F = .0000
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
Page 4                          SPSS/PC+

      * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1      Dependent Variable..  W


- - - - - - - - - - Variables in the Equation - - - - - - - - - -


Variable              B        SE B      Beta         T   Sig T

1                .03585  1.33258E-03  .97925    26.901   .0000


End Block Number  1  All requested variables entered
```

TABLE 3.3-8

STATISTICAL TESTING - OUTPUT

```
Page 3                              SPSS/PC+

        * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1       Dependent Variable..   W


Variable(s) Entered on Step Number
   1..     I



Multiple R              .97571
R Square                .95201
Adjusted R Square       .95060
Standard Error       198.80132

Analysis of Variance
                        DF       Sum of Squares         Mean Square
Regression               1      569368932.74410     569368932.74410
Residual                34       28702659.25590        844195.86047

F =     674.45123          Signif F = .0000

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Page 4                              SPSS/PC+

        * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1       Dependent Variable..   W



- - - - - - - - - - - - Variables in the Equation - - - - - - - - - -


Variable               B          SE B      Beta          T    Sig T

1                1.34064          0516    .97571     25.970    .0000


End Block Number  1  All requested variables entered
```

TABLE 3.3-9

STATISTICAL TESTING - OUTPUT

```
Page 3                              SPSS/PC+

       * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1      Dependent Variable..  W


Variable(s) Entered on Step Number
   1..     I



Multiple R                .97109
R Square                  .94303
Adjusted R Square         .94135
Standard Error         728.59863

Analysis of Variance
                         DF      Sum of Squares      Mean Square
Regression                1     278741252.99132   298741252.99132
Residual                 34      18049103.00868      530855.97084

F =     562.75387           Signif F = .0000
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
Page 4                              SPSS/PC+

       * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1      Dependent Variable..  W


- - - - - - - - - - - Variables in the Equation - - - - - - - - -

Variable                B         SE B      Beta        T   Sig T

1                  .02870  1.20987E-03   .97109    23.722   .0000

End Block Number  1  All requested variables entered
```

TABLE 3.3-10

STATISTICAL TESTING - OUTPUT

```
Page 3                          SPSS/PC+

       * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1      Dependent Variable..  W


Variable(s) Entered on Step Number
   1..     I



Multiple R                .98576
R Square                  .97172
Adjusted R Square         .97015
Standard Error         507.56740

Analysis of Variance
                       DF      Sum of Squares       Mean Square
Regression              1     159338045.10042   159338045.10042
Residual               18       4637243.89958      257624.66109

F =     618.48910          Signif F = .0000

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Page 4                          SPSS/PC+

       * * * * MULTIPLE REGRESSION THROUGH THE ORIGIN * * * *

Equation Number 1      Dependent Variable..  W



- - - - - - - - - - - Variables in the Equation - - - - - - - - - -


Variable                 B          SE B      Beta         T    Sig T

1                    .02540   1.02116E-03   .98576    24.869    .0000


End Block Number  1  All requested variables entered
```

leader follower acquisition techniques, we have demonstrated the close correlation between item unit cost and warranty cost. Therefore, competition does contribute to the determination of warranty cost -- at least in making a qualitative determination.

Another potential relationship was explored in assessing the impact of schedule on warranty cost. Schedules of various programs were studied in order to uncover a link to warranty cost. There was, however, insufficient information to establish a correlation.

The most fruitful and, perhaps, most plausible was the relationships between item unit cost to warranty cost and repair cost to warranty cost. Therefore, we have elected to structure the warranty cost estimating model around these estimating relationships.

3.4 RESEARCH EXECUTION -- MODEL DEVELOPMENT

The basic data flow of the model is depicted in Fig. 3.4-1. The model structure and rationale will be discussed in this section.

3.4.1 Basic Orientation

The model is designed to project warranty cost based on the curve shown in 3.5-6 within the range of the values presented. For example, the predicted value curve will produce a warranty cost estimate of 3.4 percent of item unit cost if the mid-ranges of the risk factors, i.e., technology, schedule concurrency, and production duration are chosen. The purpose of these risk factors is to establish upper and lower bounds for the model. Our research has shown that these areas definitely impact warranty cost decisions,

RESEARCH AND DEVELOPMENT
- Validation
  - Government Validation
  - Contractor Validation
- Full Scale Development

INVESTMENT
- Government Program Management
  - AFSC Program Office
  - AFLC Program Office
- Prime Equipment Acquisition
  - Production Hardware
  - Production Support & Service
  - Production Test & Evaluation
  - Initial Transport
- System Installation
- Support Equipment
- Initial Support Acquisition
  - Initial Spares
  - Software Investment
  - New Item Entry
  - Facilities
  - Documentation
  - Initial Training
- Product Performance Agreement

OPERATIONS AND SUPPORT
- Corrective Maintenance
- Scheduled Maintenance
- Packaging & Shipping
- Software Maintenance
- Inventory Storage
  - CONUS
  - Overseas
  - Depot
- Support Equipment Maintenance
- Document Maintenance
  - Base Technical Orders
  - Operator Manuals
  - Depot Manuals
- Sustaining Supply Support
  - Replenishment Spares
  - Supply System Management
- Recurring Training
- Engineering Changes
- Engineering & Technical Services

MISCELLANEOUS

TOTAL COST

Figure 3.4-1 LCC Cost Breakdown Structure

however direct quantitative causal relationships could not be established. For the purposes of this model, these risk factors have the following impact:

- Technology -- Discussions with hardware manufacturers have established that the degree of technology change from one product model to another has a clear impact on perceived risk. Evolutionary changes in a product that is well understood is far easier to cope with than a revolutionary change in concept or function. This is particularly true where warranties are concerned and the manufacturer may be required to perform substantial changes to a product if it fails to fulfill performance requirements

- Schedule Concurrency -- Orderly schedules where events do not overlap do not necessarily guarantee a risk free development environment. However, the converse is a virtual certainty. Weapon development schedules with high *concurrency*, *e.g.*, the completion of testing before designs are complete, or the initiation of production well before the development effort is complete. We found no quantifiable links between the level of risk and schedule concurrency, however our research and discussions with program managers in and out of government clearly shows that a relationship does exist

- Production Duration -- The period of time that the production line is operating is another area of perceived risk. Long production runs enable the manufacturer to minimize product deficiencies that may be caused by the manufacturing process itself, quality issues for example. Long production runs also allow for in-line product improvements to occur as field experience provides information about product performance.

The basic orientation of the model, therefore is to predict warranty cost using historical experience with adjustments for certain relevant risk factors. In the absence of any data to the contrary, we have elected to treat each of the risk factors equally. It could be argued that one or the other is more important, however there is no quantitative evidence to support such a contention.

Previously, in this report, we examined the possibility of establishing CERs between warranty cost and technology, schedule concurrency, and production duration. The empirical data was insufficient to statistically satisfy the requirement, however, it is known that these factors do have an impact. For example:

- The use of a warranty is an approach toward reducing certain program risks. Program Managers agree that advancing technology either separately or in conjunction with schedule concurrency sharply increases risk
- The dollar value of the risk that accrues from technology, concurrency, and production duration vary with the perceptions of the manager involved and the risk tolerance of that person. High risk programs will typically budget extra dollars (where it is feasible to do so) to cover "unknown unknowns."

Although the above factors cannot be quantified, they do exist and help shape how program risks may impact the cost of reducing them. In order to address these areas, we felt it prudent to bound the results the model produces. The basic model output produces the nominal warranty cost for a low risk program. The nominal value can then be adjusted for various risks by a multiplier that are all positive because they respond to a departure from the nominal value.

3.4.2 Model Operation

The user of this model need only supply a minimum of data/information to obtain a warranty cost estimate. The steps in the process are as follows:

- Item Unit Cost -- Enter the item unit cost or average unit cost for the production lot under consideration. Typically, item cost will vary with each production lot as will the warranty cost. Warranty costs for each lot should be estimated separately since the costs will vary and usually the warranty period of performance is different. Warranty provisions may specify a period of performance that is begun with the delivery of the first item. For example, the total period may be five years, but the second lot would have just four year of coverage and so forth. Since hardware costs are a key element in establishing current and out-year budgets, they are normally available at the time warranty analysis is being conducted

- Nominal Value -- After unit cost is entered, the model (once the software is developed) will automatically make a calculation for the nominal estimate of the warranty cost. This calculation produces a cost estimate that will be on the predicted cost curve as shown in Fig. 3.3-6. The next three steps will apply adjustments to the estimate to account for risk associated with technology, schedule concurrency, and production duration

- Technology -- The degree of technology change or advancement will have an impact on risk. Dramatic advanced in technology is typically riskier than more modest changes. The objective is to adjust the nominal warranty cost to recognize where risk has been increased due to technology.

In the automated version of the model, the user will be led through a series of screens enabling a decision as to whether the technology for the product under consideration is evolutionary, state of the art, or revolutionary. The value of the multiplier to adjust the nominal estimate already calculated is the cube root of the parameter chosen divided by the nominal value. For example:

$$\frac{4.0}{3.4}^{1/3} = 1.2^{1/3} = 1.06$$

Where:

- 4.0 is the percentage value of the upper boundary of the linear relationship depicted in Fig. 3.3-6
- 3.4 is the percentage value of the predicted curve
- 1.06 is the multiplier

In this case, 1.06 would be used if the technology change was deemed to be revolutionary. To calculate the multiplier for an evolutionary change perform the calculation described above to produce a value of 0.94. If the state of technology was determined to be state of the art, then the multiplier is 1.0 and no adjustment would be made to the nominal estimate.

- Schedule Concurrency -- Although the degree schedule concurrency may be somewhat easier to estimate than the state of technology the user will be led through a screen or two to facilitate the most reasonable choice. Recall that highly concurrent development and production schedules significantly increase program risk
- Production Duration -- The length of the production schedule will also impact program risk. A short (less than three years) run

tends to increase risk since the manufacturer has little opportunity for the product to mature in the field before production is complete. Therefore, any significant equipment problems that requires product re-design and retrofit will be more expensive when the line is shut down as compared to making in line improvements before deployment is complete

- Warranty Cost -- Following the risk factors, the next several steps present warranty cost in a variety of ways. Annual unit warranty cost (the cost per year to warrant one item) is the direct product of the model's operation to this point. If it is necessary or desirable to determine total unit warranty cost, then the duration of the warranty in years must be multiplied by the annual unit cost. Total warranty cost can then be determined by multiplying total unit cost by the number of units to be covered. The software will be developed to assist the user in making these calculations over the desperate years of warranty coverage.

Based on the available data, the model can be used with any hardware system. We know of no existing performance oriented software warranties and do no recommend the use of the model in this area.

3.4.3 Sample Cases

To illustrate the operation of the model two examples will be provided. Suppose that a piece of equipment was being purchased that had the following program characteristics:

- Item unit cost of $100,000
- Revolutionary technology
- Highly concurrent schedule
- Two year production run.

The warranty cost estimate for this product would be \$4049 per unit per year. (The estimate can be verified by referring to Fig. 3.3-6.) The calculations to determine the estimate are:

$$100{,}000 \times 0.34 \times 1.06 \times 1.06 \times 1.06 = \$4049$$

To further illustrate, suppose the following program characteristics:

- Item unit cost of \$120,000
- Evolutionary technology
- Highly concurrent schedule
- Six year production run.

The estimate therefore:

$$\$120{,}000 \times 0.34 \times 0.94 \times 1.06 \times 0.94 - 3821$$

Verify (Fig. 3.3-6) that the warranty cost lies approximately mid-way between the lower boundary and the predicted curve.

3.4.4 Model Automation

Although several references have been made in the preceding discussion to various screen presentations to assist the user through the model, the model is not automated at this point. Automation will take place during Phase IV of the project.

3.4.5 Determining Warranty Effectiveness

Beginning with our proposal for this contract and in virtually all written reports, TASC has emphasized the positive synergism that accrues to the Air Force Business Research Management

Center (AFBRMC) from the efforts expended in behalf of the Product Performance Agreement Center (PPAC).

The Statement of Work (SOW) tasks for this phase of the project are:

- "Develop a methodology that will enable the Department of Defense (DoD) to determine the effectiveness of warranties, guarantees, product performance agreements, and similar requirements"
- "Develop and validate a quantitative cost model which shall provide the program manager with an independent estimate of contract cost of a warranty.; This model must have a practical application on a day-to-day basis in the acquisition environment"
- Show how the quantitative model, described in 4.2.2 (the previous section), can be used as rationale to request a waiver of all or part of the 1985 warranty statute."

The Cost Estimating Model alone will not solve the problem of determining warranty cost effectiveness. To address the situation we recommended that the AFBRMC capitalize on the Cost Benefit Analysis (CBA) methodology previously developed for the PPAC and had already been proven successful. This recommendation is consistent with Section 2.4.3 on page 2-20 of our proposal for this project: (Proposal for Developing Quantitative Pricing Methods for Warranties in Air Force Contracts dated 29 July 1985).

Waiver of the 1985 Statute (SOW Task 4.2.3) - The Warranty Cost Model alone will not provide sufficient data to justify a waiver. The Warranty Cost Model, in conjunction with the Cost Benefit analysis from the PPAC DSS will provide sufficient justification to request a waiver under the "not cost effective" clause of the law. By utilizing the two models, DoD could quantitatively

show that the contract warranty cost (from the Warranty Cost Model) is more than the potential life cycle cost savings (from the DSS Computational Analysis Module) and therefore it wouldn't be cost effective to implement a warranty/guarantee.

This cost estimating model is one part of the equation for determining the <u>cost effectiveness</u> of a warranty approach. The other principal components are those life cycle cost (LCC) elements that may be affected by the warranty. Figure 3.4-2 presents typical LCC elements. With these key features in place, the analyst must conduct a cost benefit analysis to determine the economic utility of implementing a warranty. In the support provided to the Air Force Product Performance Agreement Center, TASC has already developed an automated Cost Benefit Analysis (CBA) methodology. However, the system operates on a large mainframe computer and that is inconsistent with the needs of the AFBRMC to have this cost model operate on a micro-computer. Since the existing CBA methodology has already been proven to be effective, we do not propose to re-invent that wheel. However, in order to meet the requirements of this project the CBA software will be re-designed to operate on a micro-computer. Appendix A to this report is an excerpt from the Decision Support System User's Guide developed by TASC for the PPAC and is provided for the purpose of re-stating our commitment of using this tested and proven CBA methodology to satisfy the requirements of the SOW.

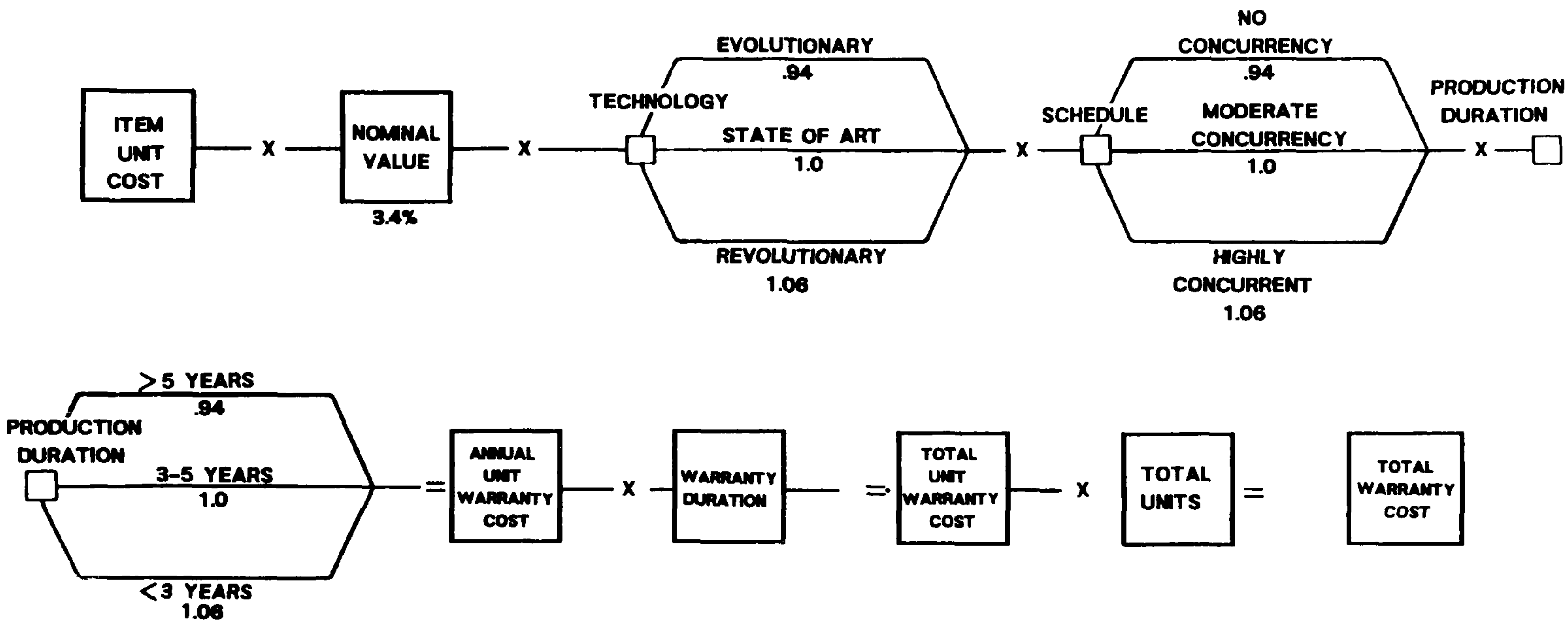

Figure 3.4-2 LCC Cost Breakdown Structure

4. CONCLUSION

The research for and development of a quantitative warranty cost estimating model has been successfully accomplished during this phase of the project.

The approach taken in this model was to restrict input requirements to those areas readily available in the day to day acquisition environment. The result is a methodology based on historical experience and responsive to the needs of the user.

With the passage of time and additional DoD warranty experience, the model can be fine tuned with additional data. However, based on the data available the evidence shows that the model is its current form will reliably predict warranty cost.

APPENDIX A

HOW TO USE THE LIFE CYCLE COST/COST BREAKDOWN STRUCTURE MODEL

CHAPTER 13
HOW TO USE THE LIFE CYCLE COST/COST BREAKDOWN STRUCTURE MODEL

This chapter describes the Life Cycle Cost/Cost Breakdown Structure Model. The first section presents some fundamental concepts. Section 13.2 describes the information you need to gather to use this model. Instructions for running the model are in Section 13.3. Section 13.4 tells you how to interpret the results of this model. A practice exercise is in the last section. This chapter assumes you are familiar with the material in Chapter 8.

13.1 FUNDAMENTAL CONCEPTS OF THE MODEL

You can use the Life Cycle Cost/Cost Breakdown Structure model (LCC/CBS) to do a Life Cycle Cost analysis for a program or to do cost/benefit analysis for a PPA or set of PPAs. The LCC/CBS model is based on the a Cost Breakdown Structure similar to that presented in Chapters 3 and 4 of the PPA DS Handbook. Figure 13-1 illustrates the Cost Breakdown Structure used in the model.

You will use this model at least twice when you are doing cost/benefit analysis. First, you will enter the cost data for the program without entering any costs associated with the PPA. This is your *baseline case*. Then you will enter the cost data for the each of the PPAs you are studying. The CAM will compare the two alternatives, and provide you a report detailing the costs and benefits of the PPA. If you are considering more than one PPA type, you should use the LCC/CBS model to study each PPA alternative.

In addition to the comparison of costs and benefits, you will need to do *sensitivity analysis*. Variation in elements such as MTBF, unit cost, turn-around time and tempo of operations can change the cost/benefit picture. Sensitivity analysis will help you to see how much impact these factors have on program costs.

RESEARCH AND DEVELOPMENT
- Validation
  - Government Validation
  - Contractor Validation
- Full Scale Development

INVESTMENT
- Government Program Management
  - AFSC Program Office
  - AFLC Program Office
- Prime Equipment Acquisition
  - Production Hardware
  - Production Support & Service
  - Production Test & Evaluation
  - Initial Transport
- System Installation
- Support Equipment
- Initial Support Acquisition
  - Initial Spares
  - Software Investment
  - New Item Entry
  - Facilities
  - Documentation
  - Initial Training
- Product Performance Agreement

OPERATIONS AND SUPPORT
- Corrective Maintenance
- Scheduled Maintenance
- Packaging & Shipping
- Software Maintenance
- Inventory Storage
  - CONUS
  - Overseas
  - Depot
- Support Equipment Maintenance
- Document Maintenance
  - Base Technical Orders
  - Operator Manuals
  - Depot Manuals
- Sustaining Supply Support
  - Replenishment Spares
  - Supply System Management
- Recurring Training
- Engineering Changes
- Engineering & Technical Services

MISCELLANEOUS

TOTAL COST

Figure 13-1. Cost Breakdown Structure for the LCC/CBS Model

13.2 WHAT YOU NEED BEFORE YOU START

The Life Cycle Cost/Cost Breakdown Structure model can require a lot of data. Gathering the information needed by the model is the most time consuming and difficult part of the cost/benefit analysis process. You should begin to collect information for the cost benefit analysis late in the full scale development phase. You will use many different sources for this information including Life Cycle Cost documentation provided by the contractor, delivery schedules, early tests of the equipment, and so forth.

Remember that the data items you need varies by PPA. Table 13-1 shows the cost elements of the Cost Model Framework and how they relate to different PPA types.

Table 13-1. Cost Element/PPA Matrix

	PPA TYPE											
COST ELEMENT	ICS	RIW	REA	LSC	AG CCR CRG EW MTB RG	MPC	IA	CLR	CSL ULG	MDG	COD	SVG
RESEARCH AND DEVELOPMENT												
Validation												
Government												
Contractor												
Full Scale Development												
Government												
Contractor												
INVESTMENT												
Government Program Management	X	X	X	X	X	X	X	X	X	X	X	X
Prime Equipment Acquisition												
Production Hardware												
Production Spt. and Svc.												
Production Test and Eval.												
Initial Transport												
System Installation	X											
System Provisioning/modif.	X											
Installation Kit Spares	X											
Support Equipment		X	X									
Hardware Acquisition		X	X									
Initial Spares		X	X									
Initial Support Acquisition	X	X	X	X	X	X						
Initial Spares (Hardware)	X	X	X	X	X	X						
Software Investment	X	X	X	X	X							
New Item Entry		X	X									
Facilities	X	X	X									
Documentation	X	X	X									
Initial Training	X	X										
Product Performance Agreement	X	X	X	X	X	X	X	X	X	X	X	X
OPERATING AND SUPPORT												
Corrective Maintenance	X	X	X	X	X	X	X	X	X	X	X	
Below Depot Level	X	X	X	X	X	X	X	X	X	X	X	
Depot Level	X	X	X	X	X	X	X	X	X	X	X	
Scheduled Maintenance		X		X	X	X	X					
Labor		X		X	X	X	X					
Materials		X		X	X	X	X					
Packaging and Shipping	X	X	X	X	X	X	X	X	X		X	
Software Maintenance	X	X	X	X	X	X	X			X		X
Inventory Storage	X	X	X	X	X	X	X	X				
SE Maintenance	X	X	X	X	X					X		
Documentation Maintenance		X	X									
Sustaining Supply Support	X	X	X	X	X	X	X	X	X			
Replenishment Spares	X	X	X	X	X	X	X	X	X			
Supply Systems Management	X	X	X	X	X	X	X	X	X			
Recurring Training		X		X								

Legend:
- AG: Availability Guarantee
- CCR: Captive Carry Reliability Guarantee
- CRG: Component Reliability Guarantee
- CLR: Chronic LRU Guarantee
- COD: Correction of Deficiencies
- CSL: Commercial Service Life Guarantee
- EW: Engine Warranty
- IA: Incentive Award
- ICS: Interim Contractor Support
- LSC: Logistics Support Cost Guarantee
- MDG: Mission Dependability Guarantee
- MPC: Maximum Parts Cost Guarantee
- MTB: MTBF-Verification Test
- REA: Repair/Exchange Agreement
- RG: Reliability Guarantee
- RIW: Reliability Improvement Warranty
- SVG: Storage Verification Guarantee
- ULG: Ultimate Life Guarantee

In the LCC/CBS model, these cost elements shown in Figure 13-1 are broken down into smaller elements. In this section, all of the elements are described. For additional descriptions, see the PPA DS Handbook or use the (H)ELP feature of the CAM. In this section, notice that some elements are marked with a *C*. These elements can be computed by the CAM if you provide their subordinate elements. The equations for computing the elements marked with a C can be found in Chapter 4 of the PPA DS Handbook. Other items are marked with a *?*. You must supply a value for these (or use the default value) if they are appropriate for the PPA you are studying. The names used for the elements in this section are the same as the names you will see on the screen. To the left of the element is its absolute item number. If an item can be copied from some other part of the LCC/CBS model, or from some other model in the CAM, this will be noted in the descriptive text.

#1 **Total Cost $** (C) — the total cost of the program for each period. You will see both discounted (or inflated) and non-discounted total cost in your output. The CAM will compute this value from the subordinate items.

#2 **Research and Development $** (C) — the total, non-discounted research and development costs. The CAM can compute this value from the subordinate items.

- #8 **Validation $** (C) — total validation costs. The CAM can compute this value from the subordinate items.
  - #10 **Government Validation $** (C) — Government validation costs for each period.
    - #12 **Total Government Valid. $** (?) — the Government's costs for validation in each period.
    - #13 **Validation Phase # Periods** (?) — the number of periods in the validation phase. This value can be copied from #15.
  - #11 **Contractor Validation $** (C) — contractor validation costs for each period.
    - #14 **Total Contractor Valid. $** (?) — the contractor's costs for validation in each period.
    - #15 **Validation Phase # Periods** (?) — the number of periods in the validation phase. This value can be copied from #13.
- #9 **Full Scale Development $** (C) — full scale development costs.
  - #16 **Government Development $** (?) — total cost, by period, of Government full scale development.
  - #17 **Contractor Development $** (?) — total cost, by period, of contractor full scale development.

#3 **Research & Dev. Inflate Index** (?) — the inflation or discount factor for the period. Note that, although this is called the inflate index, you can use either a discount factor to compute present values or an inflation factor to compute future values. Inflation and discount rates can be found in AFR-173.

#4 **Investment $** (C) — non-discounted total investment costs for the program for each period.

#18 **Government Prog. Management $** (C) — the Government's costs for managing the program in each period. This does **not** include any costs associated with administering a warranty.

#179 **AFSC Program Office $** (?) — these are the program management costs for the Air Force Systems Command program office. This value does not include any warranty administration costs.

#180 **AFLC Program Office $** (?) — these are the program management costs for the Air Force Logistics Command program office. This value does not include any warranty administration costs.

#19 **Prime Equipment Acquisition $** (C) — cost of prime equipment acquisition.

#24 **Production Hardware $** (C) — cost of production hardware.

#28 **# Systems Produced** (?) — total number of systems produced in the period. This value is also used as #31. You can copy this value from the Fixed Test Plan Model (Constant Reliability).

#29 **Avg. Cost per System $** (?) — average cost to produce one system. You can copy this value from the Fixed Test Plan Model (Constant Reliability).

#25 **Prod. Support & Service $** (?) — cost of production support and service.

#26 **Prod. Test & Eval. $** (?) — cost of production testing and evaluation.

#27 **Initial Transport $** (C) — cost of initial transport of system.

#30 **Pack. & Shipping Rate ($/lb.)** (?) — the cost per pound for packaging and shipping the system.

#31 **# Systems Produced** (?) — This is the same as #28. You can copy this value from the Fixed Test Plan Model (Constant Reliability).

#32 **System Weight (lb.)** (?) — the weight of one system in pounds.

#20 **System Installation $** (C) — cost of installing systems.

#33 **System Provisioning &Mod. $** (C) — cost of system provisioning and modification for all systems. This is also used as #37 after it is computed.

#35 **# Systems Installed** (?) — number of systems installed in the period. This value is also used as #43, #47, #84, #119, and #165.

#36 **Install. Cost per System $** (?) — the cost of installing one system.

#34 **Install. Kit Spares $** (C) — cost of installation kit spares.

#37 **System Provisioning & Mod. $** (?) — This item is the same as #33, and will be copied from there if the CAM computes it.

#38 **Factor to apply** (?) — the cost of installation kit spares is usually a percentage of the cost for system provisioning and modification. This factor is the percentage expressed as a decimal value. (e.g. .10, .20, etc.).

#21 **Support Equipment $** (C) — cost of all support equipment, including support equipment spares. This value is also used as #149 after it has been computed.

#39 **Initial SE Hardware $** (C) — cost of initial support equipment hardware. This value is also used as #53 after it has been computed.

#41 **Initial Base SE Hardware $** (C) — cost of initial base support equipment hardware.

#43 **# Systems Installed** (?) — This is the same as #35. It is also used as #47, #84, #119, and #165.

#44 **Total # Systems Installed** (?) — this is the total number of systems to be installed over the life of the program. This is also used as #166.

#45 **# Bases** (?) — the number of bases, for each period, where support equipment is installed. This is also used as #72, #79, and #88.

#46 **Avg. SE Cost per Base $** (?) — the average cost of support equipment for one base.

#42 **Depot Support Equip. $** (C) — cost of depot support equipment

#47 **# Systems Installed** (?) — this is the same as #35. This value is also used as #43, #84, #119, and #165.

#48 **Total # Systems Installed** (?) — this is the same as #44.

#49 **# Depot SE Sets** (?) — the number of support equipment sets used at depots.

#50 **Depot SE Cost per Set $** (?) — the cost of one set of depot support equipment.

#51 **First Period # of Contractor Depot Level Support** (?) — the number corresponding to the first period of Contractor Depot support. For example, if the contractor will provide depot level support for the first 3 years of the program, and your analysis begins with year 1, this value would be one.

#52 **Last Period # of Contractor Depot Level Support** (?) — the period number corresponding to the last period of contractor depot level support. For example, if the contractor will provide depot level

support for the first 3 years of the program, and your analysis begins with year 1, this value would be 3.

#40 **Support Equip. Spares $** (C) — cost of support equipment spares.

#53 **Initial SE Hardware $** (?) — this is the same as #39.

#54 **Factor to apply** (?) — Support equipment spares cost is usually a percentage of the cost of initial support equipment hardware. This value is the percentage expressed as a decimal number (e.g. .10, .20, etc.).

#22 **Initial Support Acquisition $** (C) — cost of initial support acquisition (supporting prime equipment not support equipment).

#55 **Initial Spares $** (C) — cost of initial spares for prime equipment.

#61 **Peak Operating Hrs/mo.** (?) — the peak operating hours for all systems for each period. For example, if there are 5 systems, and each system will have a peak operating hours of 50 hours per month, this value would be 250. Use a monthly value.

#62 **Avg. Spare Units $** (?) — the average cost of a spare unit. This is also used as #160. You can copy this value from the System Detailed LRU/SRU model.

#64 **Mean Time Between Fail. (hr.)** (?) — the Mean Time Between Failures in hours for the equipment for the period. This is also used as #107, #126, and #161. You can copy this value from System Detailed LRU/SRU model, the Duane Reliability Growth Model, the Exponential Reliability Model or the Fixed Test Plan Model (Exponential Reliability).

#65 **Factor for MTBF above** (?) — a factor to convert from MTBF to an operational term such as Mean Time Between Maintenance Actions or Mean Time Between Demands. This is usually a number between 0 and 1 expressed as a decimal (e.g., .10, .20). This is also used as #108, #127, and #162.

#66 **Fract. with I-level Maint.** (?) — fraction of the systems which will require repair at the Intermediate level expressed as a decimal number (e.g., .10, .20). This is also used as #112.

#68 **Base Repair Cycle Time (mo.)** (?) — the base repair cycle time (how long it takes to get something repaired at the base) in months.

#69 **CONUS Order & Ship Time (mo.)** (?) — the time it takes to order and ship a system in the Continental US in months.

#70 **O-seas Order & Ship Time (mo.)** (?) — the time, in months, it takes to order and ship a system overseas.

#71 **Fraction of Sys. O-seas** (?) — the faction of system failures which will require overseas order and shipment. This is expressed as a decimal value (e.g., .10, .20). This is also used as #129.

#72 **# Bases** (?) — this is the same as #45. It is also used in #79 and #88.

#74 **Depot Repair Cycle Time (mo.)** (?) — the number of months it takes to have equipment repaired at the depot.

#56 **Software Investment $** (?) — the cost of software included in the system.

#57 **New Item Entry $** (C) — cost of new items entered into inventory.

#75 **# New Items** (?) — the number of new items entered into inventory during the period. This the number of systems entered into the Government supply system during the period, not the number of systems produced or installed. This is also used as #183.

#76 **Avg. per New Item Entry $** (?) — the average cost of entering one new item into inventory.

#58 **Facilities $** (C) — cost of base and depot facilities.

#77 **Depot Facilities $** (?) — the cost of depot facilities.

#78 **Facilities per Base $** (?) — the cost of one base facility.

#79 **# Bases** (?) — this is the same as #45. It is also used as #72 and #88.

#59 **Documentation $** (C) — cost of documentation

#80 **Base Tech Orders $** (C) — cost of base tech orders.

#82 **Operations Manual $** (?) — the costs for one base operations manual.

#83 **Base Repair Tech Orders $** (?) — the cost for one base repair technical orders manual.

#84 **# Systems Installed** (?) — this is the same as #35. It is also used as #43, #47, #119 and #165.

#85 **# Pages per Oper. Manual** (?) — the number of pages in the base operations manual. This is also used as #152.

#86 **# Copies Base Tech Orders** (?) — the number of copies of the base repair technical orders manual for each base.

#87 **# Pages per Base Tech Copy** (?) — number of pages in one base tech orders copy. This is also used as #151.

#88 **# Bases** (?) — this is the same as #45. It is also used as #72 and #79.

#89 **Standard per Page $** (?) — the standard per page cost for making copies. This is also used as #94.

#81 **Depot Tech Orders $** (C) — cost of depot tech orders.

#90 **Depot Manual $** (?) — the cost of a depot manual.

#91 **# Copies Depot Tech Orders** (?) — the number of copies of depot repair technical orders needed for each depot.

#92 **# Pages per Depot Manual** (?) — the number of pages in one Depot manual copy. this is also used as #154.

#93 **# Depots** (?) — the number of depots which will need manuals.

#94 **Standard per Page $** (?) — this is the same as #89.

60 **Initial Training $** (?) — base and depot initial training costs. This is also used as #168.

#23 **Product Perform. Agreement $** (C) — cost of the PPA.

#95 **Price of PPA $** (?) — the amount paid to the contractor, by period, for the PPA. You can copy this value from the Warranty Price Estimating Model.

#175 **Govt. PPA Administration $** (C) — the per period cost to the Government for managing the PPA.

#176 **Using Command Expense $** (?) — this is the warranty administration expense incurred by the specific Command(s) which will use the equipment.

#177 **AFSC Expense $** (?) — this is the warranty administration expense incurred by the Air Force Systems Command.

#178 **AFLC Expense $** (?) — this is the warranty administration expense incurred by the Air Force Logistics Command.

#5 **Investment Inflate Index** (?) — inflation or discount factors for total investment costs for each period. Note that although this is called the inflate index, you can use a discount factor to get present values or an inflation factor to get future values. These factors can be found in AFR-173.

#6 **Operations and Support $** (C) — operation and support costs for each period. (Non-discounted).

#97 **Corrective Maintenance $** (C) — cost of corrective maintenance.

#106 **Total Operating Hours** (?) — the total operating hours for **all** systems operating in the period. For example, if there are 2 systems operating in period 1, and each operates for 100 hours, total operating hours for period 1 is 200 hours. If 2 more systems are installed in period 2, and all 4 systems operate for 100 hours, total operating hours in period 2 is 400 hours. This is also used as #125 and #158. You can copy this value from the Duane Reliability Growth Model.

#107 **Mean Time Between Fail. (hr.)** (?) — this is the same as #64. It is also used as #126 and #161. You can copy this value from the System Detailed LRU/SRU model, the Duane Reliability Growth Model, the Exponential Reliability Model or the Fixed Test Plan Model (Exponential Reliability).

#108 **Factor for MTBF above** (?) — this is the same as #65. It is also used as #127 and #162.

#109 **Mean Time To Repair(O-lvl,hr.)** (?) — the average time, in hours, required to repair or replace a system at the organizational level. You can copy this value from the System Detailed LRU/SRU model.

#110 **Fract. with O-level Maint.** (?) — the fraction of the failures which require O-level maintenance expressed as a decimal number (e.g.,.10, .20).

#111 **Mean Time to Repair(I-lvl,hr.)** (?) — the mean time, in hours, required to repair or replace a system at the intermediate level. You can copy this value from the System Detailed LRU/SRU model.

#112 **Fract. with I-level Maint.** (?) — this is the same as #66.

#113 **Mean Time To Repair(D-lvl,hr.)** (?) — the mean time, in hours, required to repair or replace a system at the depot level. You can copy this value from the System Detailed LRU/SRU model.

#114 **Fract. with D-level Maint.** (?) — the fraction of the failures which require D-level maintenance expressed as a decimal number (e.g., .10, .20). This is also used as #164.

#115 **Base Labor Rate ($/hr.)** (?) — the labor rate, in $ per hour, for base personnel who perform the base maintenance actions.

#116 **O-level Mater. Consump.($/hr.)** (?) — the material consumption rate, in $ per hour, for repair at the O-level.

#117 **I-level Mater. Consump.($/hr.)** (?) — material consumption rate, in $ per hour, for repairs at the I-level.

#118 **D-level Mater. Consump.($/hr.)** (?) — material consumption rate, in $ per hour, for repairs at the depot.

#173 **Depot Labor Rate ($/hr.)** (?) — the labor rate, in $ per hour, for depot personnel who perform the depot maintenance actions.

#98 **Scheduled Maintenance $** (C) — cost of scheduled maintenance.

#119 **# Systems Installed** (?) — This is the same as #35. It is also used as #43, #47, #84, and #165.

#120 **Freq. Sched. Maint.(#/period)** (?) — the number of scheduled maintenance actions in the period.

#121 **Avg. Sched. Maint. Time (hr.)** (?) — the average time, in hours, for a scheduled maintenance action.

#122 **Labor Rate ($/hr.)** (?) — the labor rate, in $ per hour, for personnel who perform the scheduled maintenance actions.

#123 **Sched. Mater. Consumption($/hr)** (?) — the materials consumption rate, in $ per hour, for scheduled maintenance actions.

#99 **Packaging & Shipping $** (C) — cost of packaging and shipping during the operations and support period.

#125 **Total Operating Hours** (?) — this is the same as #106. It is also used as #158. You can copy this value from the Duane Reliability Growth Model.

#126 **Mean Time Between Fail.(hr.)** (?) — this is the same as #64. It is also used as #107 and #161. You can copy this value from the System Detailed LRU/SRU model, the Duane Reliability Growth Model, the Exponential Reliability Model or the Fixed Test Plan Model (Exponential Reliability).

#127 **Factor for MTBF above** (?) — this is the same as #65. It is also used as #108 and #161.

#128 **CONUS Ship. Rate ($/lb.)** (?) — the shipping rate, in $ per pound, for shipping systems in the Continental US.

#129 **Fraction of Sys. O-seas** (?) — this is the same as #71.

#130 **O-seas Ship. Rate($/lb.)** (?) — the shipping rate, in $ per pound, for systems shipped overseas.

#131 **Avg. Spare Unit Weight (lb.)** (?) — average weight, in pounds of spare parts within a system/LRU. You can copy this value from the System Detailed LRU/SRU Model.

#132 **Condemnation Rate** (?) — the condemnation rate for systems, e.g., the percentage of systems that will be condemned in the period. This value cannot be greater than 1. This is also used as #159.

#133 **Unverified Fail. Probability** (?) — the probability that a failure will not be verifiable.

#174 **Fract. with D-level Maint.** (?) — This is the same as #114.

#100 **Software Maintenance $** (C) — cost of software maintenance.

#134 **Programmer Payroll $** (?) — the cost, per period, for one programmer.

#135 **Prgmr. Turnover Rate** (?) — the fraction of programmers who are new each period expressed as a decimal number (e.g. .10, .20, etc.)

#136 **Cost to Train 1 Programmer $** (?) — the cost of training one programmer.

#137 **Fraction Software Chg./Period** (?) — the fraction of the total lines of software that must be changed each period expressed as a decimal number (e.g. .10, .20, etc.).

#138 **# Lines Software Total** (?) — the total number of lines of software in the system.

#139 **Overhead Rate** (?) — the overhead rate expressed as a decimal number, not a percent. For example, 1.25 is the overhead rate corresponding to a 125% overhead.

#140 **# Lines per Programmer/Period** (?) — the average number of lines of working software one programmer can write and test in one period.

#101 **Inventory Storage $** (C) — cost of inventory storage for system items.

#141 **Storage Rate CONUS ($/cu.ft.)** (?) — inventory storage charges in $ per cubic foot for items stored at Continental US bases.

#142 **# Items at CONUS Bases** (?) — the number of items stored at Continental US bases in each period.

#143 **Storage Rate O-seas ($/cu.ft.)** (?) — inventory storage charges, in $ per cubic foot, for items stored overseas.

#144 **# Items at O-seas Bases** (?) — the number of items stored at overseas bases in each period.

#145 **Stor. Rate at Depot ($/cu.ft.)** (?) — inventory storage charges, in $ per cubic foot, for items stored at the depot.

#146 **# Items at Depot Total** (?) — total number of items stored at the depot in each period.

#147 **Average Item Weight (lb.)** (?) — the average weight of the item in pounds.

#148 **Avg. Vol/Wt. Ratio(cu.ft./lb.)** (?) — the average number of cubic feet of space for one pound of unit weight.

#102 **Support Equip. Maint. $** (C) — cost of maintaining support equipment.

#149 **Support Equipment $** (?) — this is the same as #21.

#150 **Factor to apply** (?) — The cost of support equipment maintenance is normally a percentage of the support equipment cost. This factor is the percentage, expressed as a decimal fraction (e.g., .10, .20, etc.)

#103 **Document Maintenance $** (C) — cost of document maintenance.

#151 **# Pages per Base Tech Copy** (?) — this is the same as #87.

#152 **# Pages per Oper. Manual** (?) — this is the same as #85.

#153 **Base Tech Ord. Manage($/page)** (?) — the management cost, per page, for maintenance of the base repair technical orders manual.

#154 **# Pages per Depot Manual** (?) — this is the same as #92.

#155 **Depot Tech Ord. Manage($/page)** (?) — the management cost, per page, for maintenance of the depot repair technical orders manual.

#104 **Sustaining Supply Support $** (C) — cost of sustaining supply support.

#156 **Replenishment Spares $** (C) — cost of replenishment spares.

#158 **Total Operating Hcurs** (?) — this is the same as #106. It is also used as #125. You can copy this value from the Duane Reliability Growth Model.

#159 **Condemnation Rate** (?) — this is the same as #132.

#160 **Avg. Spare Units $** (?) — this is the same as #162. You can copy this value from the System Detailed LRU/SRU model.

#161 **Mean Time Between Fail. (hr.)** (?) — this is the same as #64. It is also used as #107 and #126. You can copy this value from the System Detailed LRU/SRU model, the Duane Reliability Growth Model, the Exponential Reliability model or the Fixed Test Plan Model (Exponential Reliability).

#162 **Factor for MTBF above** (?) — this is the same as #65. It is also used as #108 and #127.

#157 **Supply System Management $** (C)

#163 **Inventory Manage/New Item $** (?) — the average cost of managing a new item in the inventory.

#183 **# New Items** (?) — this is the same as #75.

#105 **Recurring Training $** (C) — cost of recurring training.

#165 **# Systems Installed** (?) — this is the same as #35. It is also used as #43, #47, #84, and #119.

#166 **Total # Systems Installed** (?) — this is the same as #44.

#167 **Factor to apply** (?) — the factor to be applied to initial training costs in estimating recurring training costs. This value is expressed as a decimal fraction (e.g., .10, .20, etc.).

#168 **Initial Training $** (?) — this is the same as #60.

#181 **Engineering Changes $** (?) — the cost of engineering changes to the system during the operations and support phase.

#182 **Engineering & Tech. Services $** (?) — the cost of contractor engineering and technical services during the operation and support phase of the system.

#7 **Oper.& Support Inflate Index** (?) — the inflation or discount factors for operations and support costs for each period. Note that although this is called inflate index,

you can enter either a discount factor to get present values or an inflation factor to get future values. These factors are available from AFR-173.

#171 **Miscellaneous $** (?) — miscellaneous program costs not otherwise listed.

#172 **Miscell. $ Inflate Index** (?) — inflation or discount factors for miscellaneous costs for each period. Note that although this is called inflate index, you can enter either a discount factor to get present values or an inflation factor to get future values. These factors are available from AFR-173.

That is quite a long list of elements. Remember, though, that for a given PPA, you will only need to enter some of the data. If a cost element does not change between two cases, there is no reason to include it in your analysis. Appendix C contains the complete breakdown structure for each PPA type.

In addition, you can copy a lot of data elements from the previous models you have run. Remember that you don't have to enter the data at the lowest level in the breakdown. If your data is already summarized, you can enter higher levels. For instance, suppose you know the total Investment, Operations and Support and Miscellaneous costs for the alternatives you are studying. You could just enter those numbers and the CAM could still compute the costs and benefits.

13.3 RUNNING THE LIFE CYCLE COST/COST BREAKDOWN STRUCTURE MODEL

In this section, the data entry screens show the screen before any data is entered. However, there are some sample outputs which do show values. The data from Appendix D of the PPA DS Handbook was used used to create the examples. In this appendix much of the data was already computed. The illustrations you see in this section will not go to the lowest level of the breakdowns in the CAM. You will not see the level of detail given in the previous section. The LCC/CBS model works in the same way regardless of the level of detail you enter.

To run the LCC/CBS model, start up the CAM following the instructions in Chapter 8. If this is a new session, load any cases that you want to copy results from. There are instructions for doing this in Chapter 8. The data from the models you have run in this session is already available to you.

After you complete the start-up procedure, you will see the screen shown in Figure 13-2.

You do not need to do anything on this screen. Use the @ command to put the cursor in the command area, then use the (N)EXT command to go on. The next screen you see looks like Figure 13-3.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
                 BREAKDOWN OF : < (#    0) TOTAL COST $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)     1*TOTAL COST $        >        0./          0./          0./
 2)                                    0./          0./          0./

13) LIST ITEM #'S TO REPEAT-              0 /
14) LIST ITEM #'S TO COMPUTE-             1 /

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-      0/     0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-2. LCC/CBS Model Top Level Screen

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
                 BREAKDOWN OF : < (#    1) TOTAL COST $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)     2-RESEARCH AND DEVELOPMENT $    >     0./        0./        0./
 2)                                           0./        0./        0./
 3) ?   3-RESEARCH & DEV. INFLATE INDEX       1./        1./        1./
 4)                                           1./        1./        1./
 5)     4*INVESTMENT $                        0./        0./        0./
 6)                                           0./        0./        0./
 7) ?   5*INVESTMENT INFLATE INDEX            1./        1./        1./
 8)                                           1./        1./        1./
 9)     6*OPERATIONS AND SUPPORT $            0./        0./        0./
10)                                           0./        0./        0./
11) ?   7*OPER.& SUPPORT INFLATE INDEX        1./        1./        1./
12)                                           1./        1./        1./
13) LIST ITEM #'S TO REPEAT-              0 / 0/ 0/ 0/ 0/ 0/
14) LIST ITEM #'S TO COMPUTE-             5 / 9/ 0/ 0/ 0/ 0/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-      0/     0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-3. LCC/CBS Model Example Data Entry Screen 1

Notice that this screen includes the major elements of the Cost Breakdown Structure — Research and Development, Investment, and Operations and Support Cost. If you look at the compute list, you will notice that only items 5 (Investment) and 9 (Operations and Support Cost) are in it. Remember that Research and Development costs don't usually apply to an RIW PPA. If you need to include R&D costs (perhaps you are comparing the RIW with an alternative that does use R&D costs), you could modify the compute list so that item 1 will also be computed.

If you want your total costs presented as present or future values, you must enter the appropriate inflation or discount factors on this screen. Recommend you use the product of the OSD(C) Inflation Index per AFR 173-13 times the 10 percent discount rate factor appropriate for each year per AFR 178-1. After you have finished entering the data, ust the @ command or the RETURN key to put the coursor in the command area. Then use the (N)EXT command to go on. You will see the screen shown in Figure 13-4.

```
                        LCC/COST BREAKDOWN STRUCTURE MODEL
                     BREAKDOWN OF : < (#     1) TOTAL COST $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #            "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1) ?171-MISCELLANEOUS $           >        0./         0./         0./
 2)                                         0./         0./         0./
 3) ?172-MISCELL. $ INFLATE INDEX           1./         1./         1./
 4)                                         1./         1./         1./

13) LIST ITEM #'S TO REPEAT-               0 / 0/
14) LIST ITEM #'S TO COMPUTE-              0 / 0/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-       0/     0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-4. LCC/CBS Model Example Data Entry Screen 3

If you have miscellaneous costs, enter them on this screen. Also enter the inflation or discount factor for these costs if appropriate. Then use the @ command or the RETURN key to put the cursor in the command area. Use the (N)EXT command to go on. The screen will look like Figure 13-5.

On this screen, all the items approptiate to an RIW PPA are set for compute. If you have a value for one of these items already, you can type it in. Then take the item out of the compute list and you won't see a further breakdown. After you finish entering data, use the @ command or the RETURN key to put the cursor in the command area. Use the (N)EXT command and you will see the screen in Figure 13-6.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
                 BREAKDOWN OF : < (#    4) INVESTMENT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #            "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    18*GOVERNMENT PROG. MANAGEMENT $ >      0./       0./       0./
 2)                                            0./       0./       0./
 3)    19-PRIME EQUIPMENT ACQUISITION $        0./       0./       0./
 4)                                            0./       0./       0./
 5)    20-SYSTEM INSTALLATION $                0./       0./       0./
 6)                                            0./       0./       0./
 7)    21*SUPPORT EQUIPMENT $                  0./       0./       0./
 8)                                            0./       0./       0./
 9)    22*INITIAL SUPPORT ACQUISITION $        0./       0./       0./
10)                                            0./       0./       0./
11)    23*PRODUCT PERFORM. AGREEMENT $         0./       0./       0./
12)                                            0./       0./       0./
13) LIST ITEM #'S TO REPEAT-                0 / 0/ 0/ 0/ 0/ 0/
14) LIST ITEM #'S TO COMPUTE-                1/ 7/ 9/11/ 0/ 0/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-        0/     0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-5. LCC/CBS Model Example Data Entry Screen 3

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
              BREAKDOWN OF : < (#   21) SUPPORT EQUIPMENT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #            "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    39*INITIAL SE HARDWARE $     >        0./        0./        0./
 2)                                          0./        0./        0./
 3)    40*SUPPORT EQUIP. SPARES $            0./        0./        0./
 4)                                          0./        0./        0./

13) LIST ITEM #'S TO REPEAT-                0 / 0/
14) LIST ITEM #'S TO COMPUTE-               1 / 3/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-        0/     0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-6. LCC/CBS Model Example Data Entry Screen 4

Both of the items on this screen are set for compute. Notice that there are no question marks (?) next to these items.If you have lower level data for these items, use the @ command to put the cursor in the command area. Then use the (N)EXT command to go on. If you do that, you will see a screen which contains the breakdown of support equipment hardware. If you have data for

the items shown on this screen, you can enter it. Then take the items out of the compute list. Figure 13-7 shows how the screen looks when you do this.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
             BREAKDOWN OF : < (#    21) SUPPORT EQUIPMENT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    39*INITIAL SE HARDWARE $      1446992/    2241203/    2241203/
 2)                                  1120602/         0./         0./
 3)    40*SUPPORT EQUIP. SPARES $    144699 /    224120 /    224120 /
 4)                                  112060 /         0./         0./

13) LIST ITEM #'S TO REPEAT-               0 / 0/
14) LIST ITEM #'S TO COMPUTE-              0 /0 /

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-     > 0/      0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-7. LCC/CBS Model Example Data Entry Screen 5

After you have entered the data for support equipment (either as shown in Figure 13-7 or by proceeding through the breakdown screens), the screen will look like Figure 13-8, assuming that you did not change the compute list in Figure 13-5.

You will repeat the process of entering data, changing the compute list if appropriate, and using the (N)EXT command to move through the LCC/CBS model.

```
                 LCC/COST BREAKDOWN STRUCTURE MODEL
        BREAKDOWN OF : < (#   22) INITIAL SUPPORT ACQUISITION $ >
  ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    55*INITIAL SPARES $           >       0./        0./        0./
 2)                                          0./        0./        0./
 3) ?  56*SOFTWARE INVESTMENT $              0./        0./        0./
 4)                                          0./        0./        0./
 5)    57*NEW ITEM ENTRY $                   0./        0./        0./
 6)                                          0./        0./        0./
 7)    58*FACILITIES $                       0./        0./        0./
 8)                                          0./        0./        0./
 9)    59*DOCUMENTATION $                    0./        0./        0./
10)                                          0./        0./        0./
11) ?  60*INITIAL TRAINING $                 0./        0./        0./
12)                                          0./        0./        0./
13) LIST ITEM #'S TO REPEAT-               0 / 0/ 0/ 0/ 0/ 0/
14) LIST ITEM #'S TO COMPUTE-              1 / 5/ 7/ 9/ 0/ 0/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-       0/     0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-8. LCC/CBS Model Example Data Entry Screen 6

At some point, you will come to a screen which contains the item you want to use for sensitivity analysis. In this example, we are going to use packing and shipping costs for sensitivity analysis. In many cases, you will use lower level items such as MTBF. In this case, we want to see what happens to the costs and benefits for an RIW PPA if our estimates for packing and shipping are off by $300. As you go through the model, you come to a screen that looks like Figure 13-9.

You will enter the data on this screen just as you have on other screens, changing the compute list if needed. Before you give the (N)EXT command, use the @ command or the RETURN key to put the cursor in the first data entry field for Item 16. This is where you give the instructions for sensitivity analysis. The first field is for the item number for the analysis. Note that you must enter the screen item number here — the leftmost number you see. To do a sensitivity analysis for packaging and shipping costs, type 5 and press RETURN.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
              BREAKDOWN OF : < (#    6) OPERATIONS AND SUPPORT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #          "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    97*CORRECTIVE MAINTENANCE $     >       0./        0./        0./
 2)                                            0./        0./        0./
 3)    98*SCHEDULED MAINTENANCE $              0./        0./        0./
 4)                                            0./        0./        0./
 5)    99*PACKAGING & SHIPPING $               0./        0./        0./
 6)                                            0./        0./        0./
 7)   100*SOFTWARE MAINTENANCE $               0./        0./        0./
 8)                                            0./        0./        0./
 9)   101*INVENTORY STORAGE $                  0./        0./        0./
10)                                            0./        0./        0./
11)   102*SUPPORT EQUIP. MAINT. $              0./        0./        0./
12)                                            0./        0./        0./
13)  LIST ITEM #'S TO REPEAT-               0 / 0/  0/  0/  0/  0/
14)  LIST ITEM #'S TO COMPUTE-              1 / 3/  5/  7/  9/11/

16)  SENSITIVITY:ITEM#,+DELTA,#TIMES-       0/      0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-9. LCC/CBS Model Example Data Entry Screen 7

Now the cursor moves to the second field. In this field, you enter the *delta*. The CAM does sensitivity analysis by *adding* the number in this field to the costs you enter or it computes. The delta in this example is 300 dollars. Type 300 and press return. If you want the CAM to subtract a delta, type a minus sign (-) before the number. For example, to subtract 133 from a cost element, type -133. If you want to look at both subtraction and addition, you need to do the sensitivity analysis twice. One time, you enter a positive delta, then the next time, you enter a negative delta. After you enter the delta, the cursor will be in the third field. Here you enter the number of times that the delta should be applied to the cost element. In this example, we want to run the sensitivity analysis four times. Type 4 and press RETURN. This tells the CAM to show us what the effect on costs and benefits will be if the estimate for packaging and shipping is low by $300, $600, $900, and $1200. It will apply the delta to the costs for each period. Figure 13-10 shows how the screen looks after the data and the sensitivity analysis instructions have been entered.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
           BREAKDOWN OF : < (#    6) OPERATIONS AND SUPPORT $ >
 ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    97*CORRECTIVE MAINTENANCE $       >    686./    1670./   2475./
 2)                                          2684./    2445./  31431./
 3)    98*SCHEDULED MAINTENANCE $               0./       0./      0./
 4)                                             0./       0./ 238762./
 5)    99*PACKAGING & SHIPPING $              566./    1379./   2044./
 6)                                          2217./    2020./   1823./
 7)   100*SOFTWARE MAINTENANCE $                0./       0./      0./
 8)                                             0./       0./      0./
 9)   101*INVENTORY STORAGE $                   0./       0./      0./
10)                                             0./       0./      0./
11)   102*SUPPORT EQUIP. MAINT. $           27453./   74892./ 122331./
12)                                        146050./ 146050./ 895530./
13) LIST ITEM #'S TO REPEAT-                 0 / 0/ 0/ 0/ 0/ 0/
14) LIST ITEM #'S TO COMPUTE-                0 / 0/ 0/ 0/ 0/ 0/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-      >5 >300     >4 /
COMMAND: >
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-10. LCC/CBS Model Data Entry Screen with Sensitivity Analysis

Figures 13-11 through 13-12 illustrate some of the other data entry screens you will see in the LCC/CBS model.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
         BREAKDOWN OF : < (#   23) PRODUCT PERFORM. AGREEMENT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1) ? 95*PRICE OF PPA $               >        0./        0./        0./
 2)                                            0./        0./        0./
 3)   175*GOVT. PPA ADMINISTRATION $           0./        0./        0./
 4)                                            0./        0./        0./

13) LIST ITEM #'S TO REPEAT-             0 / 0/
14) LIST ITEM #'S TO COMPUTE-             3/ 0/

16) SENSITIVITY:ITEM#.+DELTA,#TIMES-     0/      0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-11. LCC/CBS Model Example Data Entry Screen 8

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
             BREAKDOWN OF : < (#    6) OPERATIONS AND SUPPORT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)   103*DOCUMENT MAINTENANCE $          >       0./         0./         0./
 2)                                               0./         0./         0./
 3)   104*SUSTAINING SUPPLY SUPPORT $             0./         0./         0./
 4)                                               0./         0./         0./
 5)   105*RECURRING TRAINING $                    0./         0./         0./
 6)                                               0./         0./         0./

13) LIST ITEM #'S TO REPEAT-                   0 / 0/ 0/
14) LIST ITEM #'S TO COMPUTE-                  1 / 3/ 5/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-           0/      0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS    "@" ENTRY->COMMAND AREA
```

Figure 13-12. LCC/CBS Model Example Data Entry Screen 9

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
           BREAKDOWN OF : < (#  104) SUSTAINING SUPPLY SUPPORT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)   156*REPLENISHMENT SPARES $          >       0./         0./         0./
 2)                                               0./         0./         0./
 3)   157*SUPPLY SYSTEM MANAGEMENT $              0./         0./         0./
 4)                                               0./         0./         0./

13) LIST ITEM #'S TO REPEAT-                   0 / 0/
14) LIST ITEM #'S TO COMPUTE-                  1 / 3/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-           0/      0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS    "@" ENTRY->COMMAND AREA
```

Figure 13-13. LCC/CBS Model Example Data Entry Screen 10

As you go through the screens, remember that you can get a further breakdown of any item which isn't marked with a ? by leaving the item in the compute list. You must enter a value for items marked with a ?, although if you simply press RETURN, the value shown on the screen will be used. The sample screens used in this section show the default values. If you have (L)OADED information from a previous case, the values from the previous case will show on the screen.

You need to enter a lot of information in the LCC/CBS model. You may should use the (S)AVE command often while using the model. You can use the (S)AVE command on any screen. If you

(S)AVE frequently, you will not lose too much data if the computer goes down or your telephone disconnects while you are in the middle of entering data.

After you have entered all the data, you will see the screen shown in Figure 13-14.

```
TO RUN CASE ISSUE A "RUN" COMMAND ON A FOLLOWING SCREEN
WHEN ALL YOUR INPUTS ARE COMPLETE.

PRESS <RETURN> TO CONTINUE-                        >
```

Figure 13-14. LCC/CBS model Ready to Run Screen

When you see this screen, you have entered all the data and can (R)UN the case (do the computations). Press the RETURN key and the screen will look like Figure 13-15.

```
                     LCC/COST BREAKDOWN STRUCTURE MODEL
                  BREAKDOWN OF : < (#    0) TOTAL COST $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #            "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    1*TOTAL COST $          >        0./           0./           0./
 2)                                     0./           0./           0./

13) LIST ITEM #'S TO REPEAT-                0 /
14) LIST ITEM #'S TO COMPUTE-               1 /

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-        0/      0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-15. LCC/CBS Model Top Level Screen Before Running

At this point, you may want to check your data, or simply save your inputs and stop. If you want to do a sensitivity analysis, and haven't already given instructions for this, you may want to do it before you run the case. If you are ready to run the case, use the @ command to put the cursor at the command line, then give the (R)UN command. The next thing you see is the screen in Figure 13-16.

```
SELECT COST (S)UMMARY,(D)ETAILED BREAKDOWN,(B)OTH,LEVEL #, OR (N)ONE>
```

Figure 13-16. LCC/CBS Model Output Options Screen

Unlike the other models, which give you your output in the same format as you gave your inputs, the LCC/CBS model can also give you a cost summary. Figure 13-16 shows your options for the summary output. (Figure 13-18 shows the summary output.) If you choose none, you will not see a cost summary. If you choose cost summary, you will see information down to the 3rd level in the Cost Breakdown Structure. If you choose a detailed breakdown, your summary will contain all the elements in the breakdown structure (there are 5 levels in the structure). You can request both a summary and a detailed breakdown. You can also specify a level number. For example, to see a summary which shows only Total Cost, Research and Development cost, Investment cost, Operations and Support cost, and Miscellaneous cost, you would use Level 2. You select your output option by typing the appropriate letter and pressing return. After you do this, the CAM will do the computations, and you will see a screen like that shown in Figure 13-17.

```
                        LCC/COST BREAKDOWN STRUCTURE MODEL
                   BREAKDOWN OF : < (#     0) TOTAL COST $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #             "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN
    *** -----   CASE COMPLETE. ENTER NEW COMMAND BELOW   ----- ***
 1)   1*TOTAL COST $              2039598./    2828157./  2887362.25/
 2)                             1843652.38/     834932./   759140.19/

13) LIST ITEM #'S TO REPEAT-               0 /
14) LIST ITEM #'S TO COMPUTE-              1 /

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-       0/      0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS    "@" ENTRY->COMMAND AREA
```

Figure 13-17. LCC/CBS Model Top Level Screen After Running

Notice the 'CASE COMPLETE' message on the fifth line of the screen. On some terminals this message will be flashing. Once a case is complete, you cannot change any data. This is a good time to save your completed case. Use the (S)AVE command (Section 8.3.7.8).

Now you can look at the results. The total costs are shown on the screen in Figure 13-17. You can use the (N)EXT and the (G)O-TO commands to see the other values the CAM has computed. However, if you have run the model with a baseline case, an important result does not show on the screen. You will need to use the (V)IEW command to see the cost/benefit analysis.

View your current output. If you chose any option other than none on the screen shown in Figure 13-16, you will see a cost summary like that shown in Figure 13-18. (You will need to use the (N)EXT command a few times to get to this part of the summary.) When you view the output on your terminal, the information shown in Figure 13-18 will be on more than one screen.

```
DATE: 29-APR-86  TIME: 15:13:37
BASELINE CASE TITLE :
             xyz receiver processor -- no ppa option
CURRENT CASE TITLE :
                xyz Receiver processor RIW option

                  SUMMARY OF COST BREAKDOWN
```

COST ELEMENT	BASELINE TOTAL COST (THOUSANDS)	CURRENT TOTAL COST (THOUSANDS)
# 1-TOTAL COST $	11,193	9,896
# 2-RESEARCH AND DEVELOPMENT $	0	0
# 8-VALIDATION $	0	0
# 9-FULL SCALE DEVELOPMENT $	0	0
# 4-INVESTMENT $	7,941	11,851
# 18-GOVERNMENT PROG. MANAGEMENT $	0	0
# 19-PRIME EQUIPMENT ACQUISITION $	0	0
# 20-SYSTEM INSTALLATION $	0	0
# 21-SUPPORT EQUIPMENT $	7,755	7,755
# 22-INITIAL SUPPORT ACQUISITION $	186	96
# 23-PRODUCT PERFORM. AGREEMENT $	0	4,000
# 6-OPERATIONS AND SUPPORT $	5,605	1,783
# 97-CORRECTIVE MAINTENANCE $	272	41
# 98-SCHEDULED MAINTENANCE $	1,084	239
# 99-PACKAGING & SHIPPING $	13	10
#100-SOFTWARE MAINTENANCE $	0	0
#101-INVENTORY STORAGE $	0	0
#102-SUPPORT EQUIP. MAINT. $	4,092	1,412
#103-DOCUMENT MAINTENANCE $	56	9
#104-SUSTAINING SUPPLY SUPPORT $	66	66
#105-RECURRING TRAINING $	23	5
#181-ENGINEERING CHANGES $	0	0
#182-ENGINEERING & TECH. SERVICES $	0	0
#171-MISCELLANEOUS $	0	0

```
NET BENEFIT         =    1297.   COST/BENEFIT RATIO   =     0.76
BENEFIT/COST RATIO  =    1.32    RETURN ON INVESTMENT =    31.86 %

    * NOTES :
      INFLATION INDICES USED WHEN APPLICABLE FOR TOTAL COST.
      ROUNDED NUMBERS SHOWN YET ACTUALS USED IN SUMMATIONS.
```

Figure 13-18. LCC/CBS Model Cost Benefit Analysis Summary Output

Even if you did not request the cost summary, the cost/benefit analysis is still in your current output. After the heading pages, you will see the non-discounted total costs just as are shown in the

screen in Figure 13-17. If you keep using the (N)EXT or page number commands, you will come to a part of the output that looks like Figure 13-19.

```
   *** COST/BENEFIT ANALYSIS RESULTS FOR: (#    1) TOTAL COST $

  TITLE OF BASELINE CASE USED :
               xyz receiver processor -- no ppa option

  COSTS ARE INCURRED FOR ALL PERIODS WHERE
  CURRENT CASE IS GREATER THAN BASELINE.
  OTHERWISE, BENEFITS ARE REALIZED.

              COSTS          BENEFITS            PERIOD/ELEMENT #
--------------------   --------------------     ----------------
               0.00        1010231.00                1
               0.00        1192797.00                2
               0.00        1360926.63                3
               0.00        1079871.13                4
               0.00         724617.25                5
         4071471.25              0.00                6
--------------------   ----------------
         4071471.25        5368443.50

      COST/BENEFIT RATIO =                0.76
      RETURN ON INVESTMENT =               0.32
                           =              31.86 PERCENT

      NET BENEFIT          =         1296972.25

 --- SENSITIVITY ANALYSIS ON ITEM- (#    99) PACKAGING & SHIPPING $

   NUMBER OF ITERATIONS=     4    DELTA =          300.00
```

Figure 13-19. LCC/CBS Model Cost/Benefit Analysis Output

If you ran a sensitivity analysis, you will also find its results in your output file. These are also cost/benefit analyses. Figures 13-20 and 13-21 show the results from the first and fourth iteration of a sensitivity analysis. If you have requested lower levels of detail for your output, you can also see how the individual cost element is affected by the sensitivity analysis.

```
*** COST/BENEFIT ANALYSIS RESULTS FOR: (#    1) TOTAL COST $

                 COSTS                  BENEFITS        PERIOD/ELEMENT #
--------------------    --------------------        ----------------
                  0.00          1009931.00                 1
                  0.00          1192524.25                 2
                  0.00          1360678.88                 3
                  0.00          1079645.88                 4
                  0.00           724412.38                 5
            4071657.25                0.00                 6
--------------------    --------------------
            4071657.25          5367192.50

       COST/BENEFIT RATIO =                   0.76
       RETURN ON INVESTMENT =                   0.32
                            =                  31.82 PERCENT

       NET BENEFIT          =             1295535.25
```

Figure 13-20. LCC/CBS Model Sensitivity Analysis Iteration 1

Section 13.4 describes the outputs and how to interpret them.

When you have finished reviewing your output, use the (C)AM command to run a different model. Use the (E)ND-CASE command to run the LCC/CBS model for a different case. Use the (D)SS or (Q)UIT commands if you have finished using the CAM. If you already saved your file, you can answer N when the CAM asks if you want to save it. If you haven't already saved your case, **save it now**.

```
    *** COST/BENEFIT ANALYSIS RESULTS FOR: (#    1) TOTAL COST $

                 COSTS                  BENEFITS        PERIOD/ELEMENT #
--------------------    --------------------        ----------------
                  0.00          1009031.00                 1
                  0.00          1191706.25                 2
                  0.00          1359935.50                 3
                  0.00          1078970.00                 4
                  0.00           723797.63                 5
            4072216.25                0.00                 6
--------------------    --------------------
            4072216.25          5363440.50

       COST/BENEFIT RATIO =                   0.76
       RETURN ON INVESTMENT =                   0.32
                            =                  31.71 PERCENT

       NET BENEFIT          =             1291224.25
```

Figure 13-21. LCC/CBS Model Sensitivity Analysis Iteration 4

13.4 INTERPRETING YOUR OUTPUTS

The LCC/CBS model will provide you with several different kinds of information. First, it will compute the Life Cycle Costs at various levels in the Cost Breakdown structure. For additional details on how the costs are computed, see the PPA DS Handbook.

Figure 13-18 illustrates the Cost Summary. The TOTAL COSTS shown in this figure reflect any inflation or discount factors you supplied. If you supplied discount factors, these are present values. If you supplied inflation factors, they are future values. All other costs in this summary are not discounted or inflated. Note that all costs are shown in thousands.

If you used a baseline case, there are four important numbers shown at the bottom of the summary: net benefit, cost/benefit ratio, benefit/cost ratio and return on investment. These numbers are all computed based on the cost and benefit numbers shown in Figure 13-19. Here, a number appears in the benefits column when the current case costs less than the baseline case. A number appears in the costs column when the current case costs more than the baseline case. The numbers shown reflect the cost differences between the two cases.

The *net benefit* is the benefits minus the costs. If this number is positive, the current case has a benefit. This is a dollar amount, and is computed from the discounted or inflated total costs.

The *cost/benefit ratio* is the ratio of costs to benefits (the sum of the costs is divided by the sum of the benefits). A cost benefit ratio of less than one indicates that the current case has a benefit over the baseline case and that this alternative would be advantageous to the government. This analysis compared an RIW option with a No PPA option for six years. During the first five years, the RIW PPA saves the Government money. The PPA requires that the Contractor pay for a lot of the maintenance. The Contractor runs the Depot, for instance. The dollar amounts (the cost difference between the two alternatives) show in the benefits column. In the sixth year, the Government spends a lot more with the RIW PPA than without it. In year six, the Government must establish depots, train personnel, and so forth. In spite of this, the PPA proves to save money over all. If the CAM tells you there is an infinite cost/benefit ratio, it means that there are no benefits, only costs.

The *benefit/cost ratio* is the inverse of the cost/benefit ratio. It is computed by dividing the total benefit by the costs. If it is greater than 1, the alternative will save the Government money.

Return on investment is the net benefit divided by the costs. Return on Investment measures how much you get for what you put in. The greater the return on investment, the more the Government will get for its money.

Notice that when you do sensitivity analysis, you get additional cost benefit analyses like those shown in Figures 13-20 and 13-21. These help you bound the risk that your estimates are incorrect.

Note that, while these results will help you make decisions about the cost effectiveness of a particular PPA, they are not the only things to consider. You will need to study various intangible factors as well.

13.5 NOW YOU TRY IT

In this section you can practice what you have learned from the chapter. The exercise outlined here will give you a chance to use the LCC/CBS model for a simple example. The data you are going to use is in the following table. You are going to study the costs and benefits of an RIW PPA. You will use the LCC/CBS model twice. First, you will enter the cost data for the program with no PPA. Then you will enter the data for the program with an RIW PPA. The data you will use is shown in Table 13-2.

Table 13-2. Data for the LCC/CBS Exercise

	NO PPA		RIW PPA	
	YEAR		YEAR	
	1	2	1	2
INVESTMENT				
Support Equipment				
Hardware Acquis.	1446992	2241203	216165	373534
Spares	144699	224120	21617	37353
Init. Support. Acq.				
Initial Spares	11000	0	0	0
Documentation Cost	75016	0	0	0
Initial Training	100000	0	0	0
PPA Price	0	0	751880	1299248
OPERATIONS & SUPPORT				
Corrective Maintenance	11437	30681	686	1670
Scheduled Maintenance	44880	122433	0	0
Packaging & Shipping	566	1502	566	1379
Support Equip. Maint.	183768	468401	27453	74892
Document Maint.	9380	9380	0	0
Sustaining Supply Spt.	11000	11000	11000	11000
Discount Factors	1.00	0.909	1.00	0.909

The data in Table 13-2 has been taken from Appendix D of the PPA DS Handbook, and the names of the cost elements used in the table are the same as those in the Appendix. Notice that much of the information has already been computed. For instance, there is a total cost for corrective maintenance. When you use the LCC/CBS model in your program, you will often enter the elements which contribute to corrective maintenance and let the LCC/CBS model compute the total for you. However, using data that has already been computed means you will have less typing in this exercise. You can concentrate on getting used to the LCC/CBS model.

1. Following the instructions in Chapter 3, connect to the PPAC VAX and log in to the DSS. You will see the DSS main menu.

2. Select the Analysis Subsystem (Option 3) from the DSS Menu. Type **3** and press **RETURN**. You will see the Analysis Selection menu. Select the Computational Analysis Module (Option 2) from this menu. Type **2** and press **RETURN**. Next you will see the PPA List Selection Screen. You are studying an RIW PPA. This PPA is on the first selection screen. Type **1** and press **RETURN** to see this screen. Then type **1** and press **RETURN** again to select the RIW PPA. Next you will see the Model Selection Menu (Figure 8-8).

3. Select the Life Cycle Cost/Cost Breakdown Structure model from this menu. Type **1** and press **RETURN**. You will see the Basic Inputs screen (Figure 8-9). Since this is your first case in this session, you want the answers shown (N) for questions 1 and 2. The cursor will be at question 3. Press **RETURN** to answer the question with A. In this exercise, you are going to keep your output file short so that there is not so much data to view when you're done. Answer Question 4 with Y to request summary information only. (When you are running a case for your program, you should choose No if you plan to use your output file to check your input data). Type **Y** and press **RETURN**. Press **RETURN** to answer Question 5 with N. (You don't have any previous data to load.) You are going to enter data for 2 years, so type **2** and press **RETURN**. Now type **T** and press **RETURN** to get the top summary level. This also helps to keep your output short! Press RETURN once more to have 2 decimal places in the displays. Now the cursor should be at the System/Project Case Title line. Type a title (you can make one up). It can be 68 characters long. After you type your title, press **RETURN**. The cursor should be at the command area. Type **N** and press **RETURN**.

4. The screen will look like Figure 13-2. Notice, however, that the screen you see only shows two fields for entering data. You analysis has two periods, so you see only two data fields. Type @ (shift-2) and press **RETURN**. Then type **N** and press **RETURN**. Next you see a screen similar to that shown in Figure 13-3.

5. On this screen you need to enter the discount rates so that the analysis will use present values. You will not be entering any data for Research and Development, but you do want to enter factors for Investment and Operations and Support. Remember that you can enter discount factors where the screen says 'inflate index.' The first place you want to enter data is in item 4. The cursor is at item 1. You can press the **RETURN** key until the cursor comes to investment inflate index. However, it is usually quicker to use the @ command. Type @ and press **RETURN** to put the cursor in the command area. Type 4 and press **RETURN** to put the cursor at Item 4 You want a discount factor of 1.00 for period 1. Just press **RETURN**. The 1 stays on the screen, and the cursor moves to period 2. Now enter the period 2 discount factor. Type **.909** and press **RETURN**. Now use the **RETURN** key to move the cursor to item 6. Enter the same discount factors for Operation and Support costs. First press **RETURN** to keep the factor 1. Then type .909 and press **RETURN**. You don't have any Miscellaneous costs, and you don't need to enter an inflation factor. Use the @ command to move to the command area. Type @ and press **RETURN**. Now use the (N)EXT command to go on. Type **N** and press **RETURN**. You will see a screen like that shown in Figure 13-22.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
                 BREAKDOWN OF : < (#    4) INVESTMENT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    18*GOVERNMENT PROG. MANAGEMENT $ >       0./       0./
 2)    19-PRIME EQUIPMENT ACQUISITION $         0./       0./
 3)    20-SYSTEM INSTALLATION $                 0./       0./
 4)    21*SUPPORT EQUIPMENT $                   0./       0./
 5)    22*INITIAL SUPPORT ACQUISITION $         0./       0./
 6)    23*PRODUCT PERFORM. AGREEMENT $          0./       0./
13) LIST ITEM #'S TO REPEAT-                  0 / 0/ 0/ 0/ 0/ 0/
14) LIST ITEM #'S TO COMPUTE-                  1/ 4/ 5/ 6/ 0/ 0/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-          0/     0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-22. Data Entry Screen 2 for the LCC/CBS Exercise

6. You do not have any data for Government program management, and the rest of the items will be broken down on subsequent screens. Use the @ command to put the cursor in the command area. Type @ and press **RETURN**. Type N and press **RETURN**. You will see the screen shown in Figure 13-23.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
             BREAKDOWN OF : < (#    21) SUPPORT EQUIPMENT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    39*INITIAL SE HARDWARE $     >       0./         0./
 2)    40*SUPPORT EQUIP. SPARES $           0./         0./

13) LIST ITEM #'S TO REPEAT-                0 / 0/
14) LIST ITEM #'S TO COMPUTE-               1 / 2/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-        0/     0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-23. Data Entry Screen 3 for the LCC/CBS Exercise.

7. You have data to enter on this screen. Notice that Items 1 and 2 could be computed. However, you are going to enter values on this screen. The cursor is at item 1. Use the value labeled hardware acquisition in Table 13-2 for initial SE hardware. Enter the NO PPA values. First, type **1446992** and press **RETURN**. Then type **2241203** and press **RETURN**. Now the cursor should be at item 3. Enter the spares values. Type **144699** and press **RETURN**. Next type **224120** and press **RETURN**. Now the cursor should be in the repeat list. Press **RETURN** twice to move the cursor to the compute list. Now you want to take the items out of the compute list since you en-

tered values for them. Type **0** and press **RETURN**. Type **0** again and press **RETURN**. Now press the **RETURN** key until the cursor moves to the command area. Type N and press **RETURN**. You will see the screen shown in Figure 13-24.

```
                        LCC/COST BREAKDOWN STRUCTURE MODEL
          BREAKDOWN OF : < (#   22) INITIAL SUPPORT ACQUISITION $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    55*INITIAL SPARES $                 >          0./          0./
 2)  ? 56*SOFTWARE INVESTMENT $                       0./          0./
 3)    57*NEW ITEM ENTRY $                            0./          0./
 4)    58*FACILITIES $                                0./          0./
 5)    59*DOCUMENTATION $                             0./          0./
 6)  ? 60*INITIAL TRAINING $                          0./          0./

13) LIST ITEM #'S TO REPEAT-                0 / 0/ 0/ 0/ 0/ 0/
14) LIST ITEM #'S TO COMPUTE-               1 / 3/ 4/ 5/ 0/ 0/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-        0/      0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS    "@" ENTRY->COMMAND AREA
```

Figure 13-24. Data Entry Screen 4 for the LCC/CBS Exercise

8. This screen shows two items for which input is needed (2 & 6) and some other items which could be computed. You have data for initial spares, documentation and initial training. First, enter the data for initial spares. Type **11000** and press **RETURN**. The cost of initial spares in period 2 is 0, so simply press **RETURN**. You don't have data for software cost, so press **RETURN** twice. This will make software cost 0 for both periods. Notice that even though software cost is marked with a question mark, you don't actually have to enter a value. When you press return, you accept the value (0) shown. Now press the **RETURN** key until the cursor is in the first field for documentation. Type 75016 and press **RETURN**. Then press **RETURN** to accept the 0 for period 2.

Now type **100000** and press **RETURN**. This is the initial training cost for period 1. The initial training cost for period 2 is 0, so simply press **RETURN**. Now the cursor should be in the repeat list. Use the return key to move the cursor to the compute list. You do not want to compute anything on the screen. Type **0** and press **RETURN** until the compute list contains all 0's. Use the @ command to put the cursor in the command area. Type @ and press **RETURN**. Type N and press **RETURN**. You will see the screen shown in Figure 13-25.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
           BREAKDOWN OF : < (#    23 PRODUCT PERFORM. AGREEMENT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #            "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1) ? 94*PRICE OF PPA $                  >          0./           0./
 2)  175*GOVT. PPA ADMINISTRATION $                 0./           0./

13) LIST ITEM #'S TO REPEAT-               0 / 0/
14) LIST ITEM #'S TO COMPUTE-              2 / 0/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-       0/       0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-25. Data Entry Screen 5 for the LCC/CBS Exercise

9. Since you are entering data for the No PPA option, you do not have any data to put on this screen. However, notice that item 2 is in the compute list. You will see the breakdown for this item. Since you don't want to see the breakdown, you need to take item 2 out of the compute list. Use the @ command to put the cursor in the command area. Type @ and press **RETURN**. Then type **14** and press **RETURN**. When the cursor moves to the repeat list, type **0** and press **RETURN**. Then use the @ command to put the cursor in the command area. Type @ and press **RETURN**. Type N and press **RETURN**. You will see the screen shown in Figure 13-26.

```
                    LCC/COST BREAKDOWN STRUCTURE MODEL
             BREAKDOWN OF : < (#     6) OPERATIONS AND SUPPORT $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #            "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN

 1)    97*CORRECTIVE MAINTENANCE $       >          0./           0./
 2)    98*SCHEDULED MAINTENANCE $                   0./           0./
 3)    99*PACKAGING & SHIPPING $                    0./           0./
 4)   100*SOFTWARE MAINTENANCE $                    0./           0./
 5)   101*INVENTORY STORAGE $                       0./           0./
 6)   102*SUPPORT EQUIP. MAINT. $                   0./           0./
 7)   103*DOCUMENT MAINTENANCE $                    0./           0./
 8)   104*SUSTAINING SUPPLY SUPPORT $               0./           0./
 9)   105*RECURRING TRAINING $                      0./           0./

13) LIST ITEM #'S TO REPEAT-             0 / 0/ 0/ 0/ 0/ 0/ 0/ 0/ 0/
14) LIST ITEM #'S TO COMPUTE-            1 / 2/ 3/ 4/ 5/ 6/ 7/ 8/ 9/

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-       0/       0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-26. Data Entry Screen 6 for the LCC/CBS Exercise

10. Notice that all the items on this screen are in the compute list. You have data for most of the fields on this screen, so you will enter it and then modify the compute list. First, enter the costs for corrective maintenance. Type **11437** and press **RETURN**. Then type **30681** and press **RETURN**. Next enter the data for scheduled maintenance. Type **44880** and press **RETURN**. Then type **122433** and press **RETURN**. Next enter the data for packaging and shipping. Type **566** and press **RETURN**. Then type **1502** and press **RETURN**. Now press the **RETURN** key until the cursor comes to the first data entry field for support equipment maintenance. Enter the data. Type **183768** and press **RETURN**. Next type **468401** and press **RETURN**.

Now enter the data for document maintenance. Here's a chance to use the repeat feature. Notice that the cost is the same in period 1 and period 2. Type **9380** and press **RETURN**. Then simply press **RETURN** for period 2. Now enter the data for sustaining supply support. You can use the repeat feature for this, too. Type **11000** and press **RETURN**. Now press **RETURN** to skip period 2. Then continue to press **RETURN** until the cursor comes to the repeat list. You want to repeat the period 1 values for items 7 and 8 across all periods. Type **7** and press **RETURN**, then type **8** and press **RETURN**. The CAM will copy the values. You will not see the values repeated on this screen, but they will be repeated for the computations. If you look at this screen again later, you will see the repeated values.

Now press the **RETURN** key until the cursor comes to the compute list. You do not want to compute any of the items on this screen, so type **0** and press **RETURN** until the compute list is all 0's. Now use the **RETURN** to move the cursor to the command line. Type N and press **RETURN**. You will see the screen shown in Figure 13-15.

11. When you see this screen, you have finished entering data. Now you are ready to run the model. Press **RETURN** to see the Top Level Screen.

12. Give the (R)UN command when you see this screen. Type **R** and press **RETURN**. Press **RETURN** and you will see the Output Option Screen (Figure 13-16). Select Cost Summary. Type S and press **RETURN**. .

When you see the screen shown in Figure 13-27, the CAM has finished the computations.

```
                        LCC/COST BREAKDOWN STRUCTURE MODEL
                     BREAKDOWN OF : < (#     0) TOTAL COST $ >
   ONLY "*" ITEMS USUALLY APPLY TO- RELIABILITY IMPROVEMENT WARRANTY
ITEM #           "?" ITEMS MUST BE INPUT OR USE VALUES SHOWN
    *** -----  CASE COMPLETE. ENTER NEW COMMAND BELOW  ----- ***
 1)    1*TOTAL COST $               2039598./    2828157./

13) LIST ITEM #'S TO REPEAT-              0 /
14) LIST ITEM #'S TO COMPUTE-             1 /

16) SENSITIVITY:ITEM#,+DELTA,#TIMES-      0/      0.0/ 0/
COMMAND:
SELECT ITEM # OR (N)EXT (B)ACK (T)OP (Q)UIT (V)IEW (L)OAD-CASE (S)AVE
(H)ELP (G)O-TO (R)UN (E)ND-CASE (C)AM (D)SS   "@" ENTRY->COMMAND AREA
```

Figure 13-27. LCC/CBS Model Top Level Screen After Running the No PPA Case

13. The case is now complete.‡ Once a case is complete, you cannot change any of the data you entered. At this point, you can use the (N)EXT command to see the values the CAM computed. You can also use the (V)IEW command to see your output. At this point, you would usually check your inputs before going on with another case. Since this is practice, you can skip this check.

14. You have now finished the No-PPA case, and it is time to do the RIW case. Use the (E)ND-CASE command. Type **E** and press **RETURN**. The CAM will give you a chance to save your case. Type the name you want to use for the case (make up any name you want) and press **RETURN**. Save your output file too. Type **Y** and press **RETURN** when the CAM asks if you want to do this. After the CAM finishes saving your files, you will see the Basic Inputs screen (Figure 8-9).

15. This time, you want to compare the new case you are working on with the previous case (your No-PPA case). Type Y and press **RETURN** to answer question 1 with Yes. If you answer question 2 with yes, the CAM will copy all the changes you made to the compute list in the last case into this case. You won't have to do all that changing again. Type **Y** and press **RETURN**. Since you have answered Yes to question 2, question 3 is meaningless. Just press **RETURN** to skip over question 3. Again, you want just summary information, so type **Y** and press **RETURN** to answer question 4 with yes. You want to copy the data from the previous case so that you won't have to do as much typing. Type **Y** and press **RETURN** to answer question 5 with yes. Now press **RETURN** until the cursor comes to the System/Project Case Title line. Enter a title for this case and press **RETURN**. When the cursor moves to the command area, type N and press **RETURN**. You will see the top level screen.

16. Notice that you see the same values that you saw at the end of the previous case. The CAM has copied all the data for you, including its results. Now you should use the (N)EXT command to move through all of the screens. On each screen, you will see the data you entered last time. Use the values for the RIW case shown in Table 13-2. If the values are the same as the ones shown on the screen, just press **RETURN** to keep the values. If the values in the table are different, type the new values. Notice that you won't have to change the compute list this time. The procedure for entering data is the same as in the previous case. If you get confused, look back over the instructions above. Don't forget to enter the PPA costs this time! Also, plan to do a sensitivity analysis on sustaining supply support. When you see the screen shown in Figure 13-26, give your sensitivity analysis instructions. Sustaining supply support is item 8. Use a delta of 1000. This is saying what if my cost estimate is low by $1000?. Do 3 iterations. This will give you a 'what if' for $1000, $2000, and $3000.

---

‡ Note: if you compare the total costs with the present value figures printed in the PPA DS Handbook, Table D.4-2, you will notice that the computed total costs are different. There is a difference of $1 in the costs for Period 1. This is simply due to rounding. However, for period 2, the table shows a total cost of 2,828,440; the CAM computes 2,828,157. This difference comes from the precision of the discount factor. The calculations for Table D.4-2 used a discount factor of .9090909. Your computations used .909. This accounts for the $283 difference. If the numbers you see are different by more than this, you probably made a typographical error when you entered data.

17. When you finish entering the data, use the (R)UN command to do the computations. Request Cost Summary output. When you see the 'CASE COMPLETE' message, use the (S)AVE command to save your case. Type **S** and press **RETURN**. Make up a name for your case file. It should be different from the name you used for the No PPA alternative. Type your file name and press **RETURN**. Answer Y to save your outputs. Type **Y** and press **RETURN**. Next you will see the screen with total costs again.

18. Use the (V)IEW command to see the cost/benefit analysis. Type **V** and press **RETURN**. You should view your current output. Type **C** and press **RETURN**. You will see the first page of the report. It will show some heading information. Use the (N)EXT command until you see the cost/benefit summary. If you want to see the results of your sensitivity analysis, continue using the (N)EXT command.‡ When you finish, use the (E)XIT command to return to the CAM. Type **E** and press **RETURN**.

NOTE

If you wish to compare and printout two previously saved cases, first "L"oad your baseline case. Second, enter "Y"es to the first question in the Basic Inputs screen, indicating that you wish to make the previous case the baseline case. Third, "L"oad the PPA case. Fourth, enter "N"o to the first question in the Basic Inputs screen. Fifth, go the the "N"ext screen and enter the "R"un command. Sixth, request the "D"SS screen. Seventh, "S"ave both the input and the output forms of your case as you go to the DSS screen. Eighth, request the "U"tilities option on the DSS main menu. Ninth, request "3", which is the print option and enter the ".out" format of your file name.

19. Now you have completed the LCC/CBS model for both the No-PPA and the PPA option. You should be at the total cost screen once more. Use the (Q)UIT command to log off the DSS. Type Q and press **RETURN**. The CAM will remind you to save your case. Since you already saved it, type @ and press **RETURN** when the CAM asks for a file name.

20. You should see the DSS logout message. Follow the disconnecting procedures for your equipment (see Chapter 3). You're done with this exercise!

‡ If you have a printer attached to your terminal, you may want to use the DSS utilities to get a printout of this file for later review.